PATENT APPLICATION

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE
BEFORE THE HONORABLE BOARD OF PATENT APPEALS AND INTERFERENCES

In re the Application of

Paul M. BUTTERFIELD et al.	On Appeal from Group: 2625
Application No.: 10/758,099	Examiner: R. ZHU
Filed: January 16, 2004	Docket No.: 117435

For: SYSTEMS AND METHODS FOR SPECTROPHOTOMETRIC ASSESSMENT OF COLOR MISREGISTRATION IN AN IMAGE FORMING SYSTEM

APPEAL BRIEF TRANSMITTAL

Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

Sir:

Attached hereto is our Brief on Appeal in the above-identified application.

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For: SYSTEMS AND METHODS FOR SPECTROPHOTOMETRIC ASSESSMENT OF COLOR MISREGISTRATION IN AN IMAGE FORMING SYSTEM

BRIEF ON APPEAL

Appeal from Group 2609
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I. REAL PARTY IN INTEREST

The real party in interest for this appeal and the present application is Xerox Corporation, by way of an Assignment recorded in the U.S. Patent and Trademark Office at Reel 014899, Frame 0071.

II. STATEMENT OF RELATED CASES

There are no prior or pending appeals, interferences or judicial proceedings, known to Appellants, Appellants' representative or the assignee, that may be related to, or that will directly affect or be directly affected by or have a bearing upon, the Board's decision in the pending appeal.

III. JURISDICTIONAL STATEMENT

The Board has jurisdiction under 35 U.S.C. §134(a). The Examiner mailed a Final Rejection on October 20, 2008, setting a three-month shortened statutory period for response. The time for responding to the Final Rejection expired on January 20, 2009, which was a Federal Holiday. Rule 134. A Notice of Appeal was timely filed on January 21, 2009, the next business day following the Federal Holiday. Time for filing an Appeal Brief expires the later of two months from the filing of the Notice of Appeal, or one month from the mailing date of the Notice of Panel Decision if a Pre-Appeal Brief Request for Review is sought. Bd. R. 41.37c and *Official Gazette Notice*, July 12, 2005. No Pre-Appeal Request for Review was sought. The extendible period for filing the Appeal Brief therefore expires March 21, 2009. This Appeal Brief is being timely filed on March 3, 2009.

IV. TABLE OF CONTENTS

Page

I. Real Party In Interest 2

II. Statement of Related Cases 3

III. Jurisdictional Statement 4

IV. Table of Contents 5

V. Table of Authorities 7

VI. Status of Amendments 8

VII. Grounds of Rejection to be Reviewed 9

VIII. Statement of Facts 10

IX. Argument 17

A. No Predictability Has Been Shown To Making The Asserted Combination Of References 17

1. Claim 1 17

a. The Asserted Combination Would Impermissibly Modify The Principle Of Operation of Klassen 19

b. The Office Action Provides No Objective Evidence To Support Making The Asserted Combination 21

c. The Asserted Basis For Combining The Applied References Is A Mere Conclusory Statement 22

2. Claim 8 24

a. The Asserted Combination Would Impermissibly Modify The Principle Of Operation of Klassen 26

b. The Office Action Provides No Objective Evidence To Support Making The Asserted Combination 28

c. The Asserted Basis For Combining The Applied References Is A Mere Conclusory Statement 29

3. Claim 20 31

a. The Asserted Combination Would Impermissibly Modify The Principle Of Operation of Klassen 33

b. The Office Action Provides No Objective Evidence To Support Making The Asserted Combination 35

c. The Asserted Basis For Combining The Applied References Is A Mere Conclusory Statement 36

B. The Conclusions Made In The Office Action May Only Be Reached Through The Impermissible Application Of Hindsight Reasoning 39

C. The Dependent Claims Would Not Have Been Rendered Obvious By The Applied References For The Additional Features They Recite 40

X. CONCLUSION 41

APPENDIX A - CLAIMS APPENDIX 42
APPENDIX B - CLAIM SUPPORT AND DRAWING ANALYSIS SECTION 48
APPENDIX C - RELATED PROCEEDINGS APPENDIX 51
APPENDIX D - EVIDENCE SECTION 52
APPENDIX E - RELATED CASES 53

V. TABLE OF AUTHORITIES

Cases	Page
In re Kahn, 441 F.3d 977 (Fed. Cir. 2006)	23, 31, 38
KSR v. Teleflex, 550 US 398 (2007), 127 S.Ct. 1727 (2007)	23, 30, 31, 38
In re Sponnoble, 405 F.2d 578, 585 160 USPQ (CCPA 1969)	40
Statutes	
35 U.S.C. §103(a)	9
Other Authorities	
Manual of Patent Examining Procedure, Revision 6, §2142 (2007)	39

VI. STATUS OF AMENDMENTS

The amendments made in the December 2, 2008 Amendment After Final Rejection were not entered. The claims stand as amended by Appellants' August 12, 2008 Amendment.

VII. GROUNDS OF REJECTION TO BE REVIEWED

The following grounds of rejection are presented for review:

1) Claims 1-9 and 14-20 are rejected under 35 U.S.C. §103(a) as being unpatentable over U.S. Patent No. 6,345,117 to Klassen in view of U.S. Patent No. 6,198,549 to Decker et al. (hereinafter "Decker") and further in view of U.S. Patent No. 5,748,221 to Castelli et al. (hereinafter "Castelli").

2) Claims 10-13 are rejected under 35 U.S.C. §103(a) as being unpatentable over Klassen in view of Decker, Castelli and further in view of what the Office Action asserts is well known.

VIII. STATEMENT OF FACTS

1. In rejecting claims 1-9 and 14-20 under 35 U.S.C. §103(a), the Office Action cites Klassen at col. 10, lines 42-62, col. 11-12, col. 13, lines 1-45, col. 13, line 66-col. 14, line 14, Abstract, Fig. 3 and Table 1, Decker at col. 1, lines 14-28, col. 4, lines 31-34, col. 5, lines 20-45, col. 5, line 62-col. 6, line 8, col. 7, lines 5-15, col. 8, lines 20-67, Abstract and Fig. 2 and Castelli at col. 3, lines 24-30 and col. 6, lines 65-67. (Office Action mailed October 20, 2008, page 3, line 7 through page, 15, line 6, hereinafter "OA p. _____, l. _____").

2. Claim 1 recites a method for detecting color misregistration and an image forming system comprising: forming a registration patch with the image forming system; calculating or selecting a combined color value for the registration patch; performing spectrophotometric analysis on the registration patch to detect a detected color value; determining if color misregistration has occurred by comparing the detected color value with the combined color value; and attaining a degree of color misregistration based on known dimensions of the misregistration patch and an amount of color shift that is represented by a ΔE color difference, between the detected color value and the combined color value.

3. Claims 2-7 depend directly or indirectly from claim 1.

4. Claim 8 recites an image forming system capable of detecting and adjusting for color misregistration comprising: a plurality of image forming stations, each image forming station forming an image in one color; a charge retentive surface which receives each image from its corresponding image forming station and transfers the combined image to a recording medium; a spectrophotometric device either attached to or integral to the image forming system; and a controller that causes the spectrophotometric device to perform detection of color misregistration based on known dimensions of the registration patch and an amount of color shift that is represented by a ΔE color difference, on at least one registration patch by comparing a detected color value of the registration patch that is detected by the spectrophotometric device to a combined color value of the registration patch that is calculated or selected.

5. Claims 9-19 depend directly or indirectly from claim 8.

6. Claim 20 recites an apparatus comprising: means for forming images; means for creating at least one registration patch having a combined color value; means for performing spectrophotometric analysis on the at least one registration patch to detect a detected color value; means for determining if color misregistration has occurred on images formed by the means for forming images by comparing the detected color value to the combined color value; means for adjusting an image forming process

to adjust for the color misregistration; and means for obtaining a degree of color misregistration based on known dimensions of the registration patch and an amount of color shift that is represented by a ΔE color difference, between the detected color value and the combined color value.

7. The Office Action concedes that Klassen does not disclose forming a registration patch with the image forming system and obtaining a degree of color misregistration based on known dimensions of the registration patch. (OA p. 4, l. 15-17).

8. The Office Action relies on Decker and Castelli as teaching forming a registration patch with the image forming system and obtaining a degree of color misregistration based on known dimensions of the registration patch. (OA p. 4, l. 18 - p. 5, l. 15).

9. The Office Action asserts that Klassen, Decker and Castelli are combinable. (OA p. 5, l. 15-22).

10. Appellants disagree.

11. The Office Action concludes that it would have been obvious to one of ordinary skill in the art at the time of the invention to modify the input image of Klassen to be printed as a registration pattern taught by Decker on a registration patch taught by Castelli with a specified dimension large enough to give an accurate assessment of overall misregistration but

small enough to fit the aperture of a color scanner to avoid any inaccuracies due to the placement of the aperture of the color scanner within a repetitive pattern and to avoid inaccuracies due to density variations caused by variations in the paper velocity through a print station. (OA p. 5, l. 15-22).

12. Appellants disagree.

13. The Office Action concludes it would have been obvious to one of ordinary skill in the art at the time of invention to modify the input image of Klassen to be printed as a registration pattern taught by Decker on a registration patch taught by Castelli so as to correctly measure the optical densities of the registration patterns. (OA p. 10, l. 6-10).

14. Appellants disagree.

15. Klassen is directed to a color printing system which deposits colors on a separation-by-separation basis that is calibrated to determine a printed color responsive to a requested color, based on a mapping of device independent colors to printer output colors (Abstract).

16. Klassen provides trapping to correct misregistration between printer output colors due to imperfect placement of the separation color (Abstract).

17. The system in Klassen includes calibration data stored in a device memory mapping a set of device independent colors to printer output

colors; a trapping processor, using calibration data to determine device independent colors for printer colors (Abstract).

18. Klassen also teaches a trapping calculation processor, converting device that converts independent colors to a color space in which equivalent color differences in human color perception are approximately equivalent values, determining whether to trap, a trap color, and a trapping location for the trapping color, and an image modification processor to alter the image in accordance with any determinations of the trapping calculating processor (Abstract).

19. Klassen teaches that a visibility vector is constructed from two colors (A, B) and a list of misregistration colors, and a list of values is built which correspond to the visibilities of all of the misregistration colors (col. 13, line 66-col. 14, line 14).

20. Klassen teaches that if the maximum entry in the visibility vector is less than a threshold value t, the misregistration will not be visible, and no action is taken for these two colors, and the next set of two colors is reviewed (col. 14, lines 2-6).

21. Klassen teaches that an electronic representation of a document from an image input terminal such as a scanner is derived in a format related to the physical characteristics of the device, and commonly with pixels defined at m bits per pixel (col. 10, lines 42-48).

22. In considering the visibility of potential misregistrations, and in creating the visibility vector for the difference in color variation of colors a and b, Klassen bases these calculations on the actual scanned image rather than a registration patch or registration pattern (col. 11, lines 30-50).

23. Decker is directed to a system, method, program and print pattern that allows print misregistration to be detected and controlled through density measurements (Abstract).

24. Decker teaches that a special print pattern is used for which a correlation between a density measurement of the print pattern and an amount of misregistration can be made (Abstract).

25. Castelli is directed to a method and apparatus for measuring colormetric, gloss and registration data on a substrate exiting a printing machine (Abstract).

26. Castelli teaches that a number of color patches are printed using toners from the target printer family using a printer representative of that family, and the color of the patches are selected so as to adequately represent the volume and surface of the printer's color gamut (col. 6, line 65 - col. 7, line 2).

27. Castelli further teaches incorporating a third detector for determining a registration value between a plurality of color separations in the image and generating a signal indicative thereof (col. 3, lines 24-28).

28. The Office Action takes official notice that the cited printing machines are well known species of genus printing machines and it is well within the knowledge of one of ordinary skill in the art to use the above-mentioned copiers and printers as the image forming system because each of the copiers and printers are qualified to perform superbly in the endeavor of color printing and they are all very well known under the sun. (OA p. 15, l. 12-16).

IX. ARGUMENT

The Office Action rejects the pending claims as having been obvious in view of the applied references. However, with respect to at least independent claims 1, 8 and 20, the law relating to obviousness is improperly applied. Proper application of the law, and reasonable interpretations of the references, demonstrates that the relevant standard for obviousness has not been met, and the claimed subject matter is allowable over the applied references.

A. No Predictability Has Been Shown To Making The Asserted Combination Of References

1. Claim 1

Klassen, Decker and Castelli would not have been predictably combined in the manner the Office Action suggests with any reasonable expectation of success at least because the asserted combination of applied references would impermissibly modify the principle of operation of, and overly complicate, the Klassen device.

Claim 1 recites a method for detecting color misregistration and an image forming system comprising: forming a registration patch with the image forming system; calculating or selecting a combined color value for the registration patch; performing spectrophotometric analysis on the registration patch to detect a detected color value; determining if color misregistration has occurred by comparing the detected color value with the combined color value; and attaining a degree of color misregistration based on known dimensions of

the misregistration patch and an amount of color shift that is represented by a ΔE color difference, between the detected color value and the combined color value. Fact 2.

The Office Action asserts that Klassen can reasonably be considered to teach many of the features positively recited in independent claim 1. The Office Action concedes that Klassen fails to disclose forming a registration patch with the image forming system and obtaining a degree of color misregistration based on known dimensions of the registration patch. Fact 7. Rather, the Office Action relies on Decker and Castelli as allegedly making up for this shortfall in the application of Klassen to the subject matter of the pending claims. Fact 8. The Office Action concludes that it would have been obvious to one of ordinary skill in the art at the time the invention was made to modify the input image of Klassen to be printed as a registration pattern as taught by Decker on a registration patch as taught by Castelli. Fact 11.

The Office Action asserts that one of ordinary skill in the art at the time the invention was made would have predictably modified the input image of Klassen to be printed as a registration pattern as taught by Decker on a registration patch as taught by Castelli with a specified dimension large enough to give an accurate assessment of overall misregistration, but small enough to fit the aperture of a color scanner, to avoid any inaccuracies due to the placement of the aperture of the color scanner within a repetitive pattern, and to

avoid inaccuracies due to density variations caused by variations in the paper velocity through a print station. Fact 11. The analysis of the Office Action fails for at least the following reason.

a. The Asserted Combination Would Impermissibly Modify The Principle Of Operation of Klassen

Klassen is directed to a color printing system that deposits colors on a separation-by-separation basis that is calibrated to determine a printed color responsive to a requested color, based on a mapping of device independent colors to printer output colors. Fact 15. The Klassen system provides trapping to correct misregistration between printer output colors due to imperfect placement of the separation color. Fact 16. Klassen teaches that a visibility vector is constructed from two colors (A, B) and a list of misregistration colors, and a list of values is built which correspond to the visibilities of all of the misregistration colors. Fact 21. Klassen teaches that if the maximum entry in the visibility vector is less than a threshold value T, the misregistration will not be visible, and no action is taken for these two colors, and the next set of two colors is reviewed. Fact 20. Klassen further teaches that an electronic representation of a document from an image input terminal such as a scanner is derived in a format related to the physical characteristics of the device, and commonly with pixels defined at m bits per pixel. Fact 21. In considering the visibility of potential misregistrations, and in creating the visibility vector for the difference in color variation of colors A and B, Klassen bases these

calculations on the actual scanned image rather than a registration patch or registration pattern. Fact 22.

By contrast, Decker teaches a system, method, program and print pattern that allows print misregistration to be detected and controlled through density measurements, not variation in colors. Fact 23.

Castelli is directed to a method and apparatus for measuring colormetric, gloss and registration data on a substrate exiting a printing machine. Fact 25. Castelli teaches that a number of color patches are printed using toners from the target printer family using a printer representative of that family, and the color of the patches are selected so as to adequately represent the volume and surface of the printer's color gamut. Fact 26. Castelli further teaches incorporating a third detector for determining a registration value between a plurality of color separations in the image and generating a signal indicative thereof. Fact 27.

Combining the applied references in the manner asserted would impermissibly modify the principle of operation of, and overly complicate, the Klassen device. There is nothing in Klassen to suggest that Klassen lacks any element that would be necessary to make the color printing system of Klassen "more accurate" such as incorporating the features of Decker and Castelli in the manner the Office Action suggests. Fact 11. Further, incorporating the features of Decker and Castelli into the Klassen device would overly complicate the Klassen device by including the additional functions, such as

forming a registration patch, as opposed to merely scanning the image itself for color misregistration. Therefore, any over-complication of Klassen would impermissibly modify the principle of operation of the Klassen device. Therefore, one of ordinary skill in the art would not have predictably modified Klassen in the manner the Office Action suggests to render obvious the subject matter of independent claim 1.

b. The Office Action Provides No Objective Evidence To Support Making The Asserted Combination

The Office Action fails to provide any objective evidence of record to support the mere conclusory statement that it would have been obvious to combine Klassen, Decker and Castelli "to avoid any inaccuracies due to the placement of the aperture of the color scanner within a repetitive pattern and to avoid inaccuracies due to density variations caused by variations in the paper velocity through a print station." Fact 11. Because no objective evidence of record has been provided in the Office Action to support the conclusion that it would have been obvious to combine a method for automatic trap selection for correcting for separation misregistration color printing of Klassen with the system for performing registration calibration for printers by measuring density of Decker and an apparatus for color imagery gloss and registration feedback in a color printing machine as taught in Castelli, the conclusion reached by the Office Action that one of ordinary skill would have predictably modified Klassen in view of Decker and Castelli is unreasonable.

c. The Asserted Basis For Combining The Applied References Is A Mere Conclusory Statement

The Office Action summarily concludes that it would have been obvious to combine Klassen, Decker and Castelli "to avoid any inaccuracies due to the placement of the aperture of the color scanner within a repetitive pattern and to avoid inaccuracies due to density variations caused by variations in the paper velocity through a print station." Fact 12. This is not a reasonable conclusion upon which to base the assertion that one of ordinary skill in the art would have predictably combined any of the teachings of the references, as is suggested by the Office Action, with any reasonable expectation of success in achieving the objectives which are intended to be achieved by, and in the manner of, the subject matter of the pending claims. In fact, there is nothing in Klassen that can reasonably be considered to have suggested that there would be any inaccuracies due to the placement of the aperture of the color scanner within a repetitive pattern and to avoid inaccuracies due to density variations caused by variations in the paper velocity through a print station.

The Office Action fails to provide any support for the mere conclusory statement regarding making the asserted combination of references. It would not have been obvious to combine a method for automatic trap selection for correcting for separation misregistration color printing of Klassen with the system for performing registration calibration for printers by measuring density of Decker and an apparatus for color imagery gloss and registration feedback in

a color printing machine as taught in Castelli. To any extent that Klassen teaches avoiding any inaccuracies due to placement of the aperture of the color scanner within a repetitive pattern and avoiding inaccuracies due to density variations caused by variations in the paper velocity through a print station, which Appellants do not concede, this is not a reasonable conclusion upon which to base the assertion that one of ordinary skill in the art would have predictably combined any of the teachings of the references as is suggested by the Office Action with any reasonable expectation of success in achieving the objectives which are intended to be achieved by, and in the manner of, the subject matter of the pending claims. There is no suggestion in Klassen that would support the Office Action's reasoning has no rational underpinning to justify the Office Action's conclusions.

Even after the Supreme Court's decision in *KSR International Co. v. Teleflex Inc.*, 550 US 398, 127 S.Ct. 1727 (2007), the analysis supporting an obviousness rejection must be explicit. The Supreme Court in *KSR* approved the conclusion set forth in the decision of the Federal Circuit in *In re Kahn*, 441 F.3d 977 (Fed. Cir. 2006), that "rejections on obviousness grounds cannot be sustained by mere conclusory statements; instead the must be some articulated reasoning with some rational underpinning to support the legal conclusion of obviousness." 550 US 398, 127 S.Ct. 1727. The standard is not met here with the mere conclusory statement that one of ordinary skill in the art may have

combined the currently-applied references "to avoid any inaccuracies due to the placement of the aperture of the color scanner within a repetitive pattern and to avoid inaccuracies due to density variations caused by variations in the paper velocity through a print station." Fact 11. In other words, there is no rational underpinning to the articulated reasoning.

* * * * *

Accordingly, no predictability has been shown in the Office Action to making the asserted combination of references. For at least this reason, the references are not combinable in the manner suggested, and the rejection based on the combination of these references necessarily fails.

2. Claim 8

Klassen, Decker and Castelli would not have been predictably combined in the manner the Office Action suggests with any reasonable expectation of success at least because the asserted combination of applied references would impermissibly modify the principle of operation of, and overly complicate, the Klassen device.

Claim 8 recites an image forming system capable of detecting and adjusting for color misregistration comprising: a plurality of image forming stations, each image forming station forming an image in one color; a charge retentive surface which receives each image from its corresponding image forming station and transfers the combined image to a recording medium; a

spectrophotometric device either attached to or integral to the image forming system; and a controller that causes the spectrophotometric device to perform detection of color misregistration based on known dimensions of the registration patch and an amount of color shift that is represented by a ΔE color difference, on at least one registration patch by comparing a detected color value of the registration patch that is detected by the spectrophotometric device to a combined color value of the registration patch that is calculated or selected. Fact 4.

The Office Action asserts that Klassen can reasonably be considered to teach many of the features positively recited in independent claim 8. The Office Action concedes that Klassen fails to disclose forming a registration patch with the image forming system and obtaining a degree of color misregistration based on known dimensions of the registration patch. Fact 7. Rather, the Office Action relies on Decker and Castelli as allegedly making up for this shortfall in the application of Klassen to the subject matter of the pending claims. Fact 8. The Office Action concludes that it would have been obvious to one of ordinary skill in the art at the time the invention was made to modify the input image of Klassen to be printed as a registration pattern as taught by Decker on a registration patch as taught by Castelli. Fact 11.

The Office Action asserts that one of ordinary skill in the art at the time the invention was made would have predictably modified the input image of

Klassen to be printed as a registration pattern as taught by Decker on a registration patch as taught by Castelli with a specified dimension large enough to give an accurate assessment of overall misregistration, but small enough to fit the aperture of a color scanner, to avoid any inaccuracies due to the placement of the aperture of the color scanner within a repetitive pattern, and to avoid inaccuracies due to density variations caused by variations in the paper velocity through a print station. Fact 11. The analysis of the Office Action fails for at least the following reason.

a. The Asserted Combination Would Impermissibly <u>Modify The Principle Of Operation of Klassen</u>

Klassen is directed to a color printing system that deposits colors on a separation-by-separation basis that is calibrated to determine a printed color responsive to a requested color, based on a mapping of device independent colors to printer output colors. Fact 15. The Klassen system provides trapping to correct misregistration between printer output colors due to imperfect placement of the separation color. Fact 16. Klassen teaches that a visibility vector is constructed from two colors (A, B) and a list of misregistration colors, and a list of values is built which correspond to the visibilities of all of the misregistration colors. Fact 21. Klassen teaches that if the maximum entry in the visibility vector is less than a threshold value T, the misregistration will not be visible, and no action is taken for these two colors, and the next set of two colors is reviewed. Fact 20. Klassen further teaches that an electronic

representation of a document from an image input terminal such as a scanner is derived in a format related to the physical characteristics of the device, and commonly with pixels defined at m bits per pixel. Fact 21. In considering the visibility of potential misregistrations, and in creating the visibility vector for the difference in color variation of colors A and B, Klassen bases these calculations on the actual scanned image rather than a registration patch or registration pattern. Fact 22.

By contrast, Decker teaches a system, method, program and print pattern that allows print misregistration to be detected and controlled through density measurements, not variation in colors. Fact 23.

Castelli is directed to a method and apparatus for measuring colormetric, gloss and registration data on a substrate exiting a printing machine. Fact 25. Castelli teaches that a number of color patches are printed using toners from the target printer family using a printer representative of that family, and the color of the patches are selected so as to adequately represent the volume and surface of the printer's color gamut. Fact 26. Castelli further teaches incorporating a third detector for determining a registration value between a plurality of color separations in the image and generating a signal indicative thereof. Fact 27.

Combining the applied references in the manner asserted would impermissibly modify the principle of operation of, and overly complicate, the Klassen device. There is nothing in Klassen to suggest that Klassen lacks any

element that would be necessary to make the color printing system of Klassen "more accurate" such as incorporating the features of Decker and Castelli in the manner the Office Action suggests. Fact 11. Further, incorporating the features of Decker and Castelli into the Klassen device would overly complicate the Klassen device by including the additional functions, such as forming a registration patch, as opposed to merely scanning the image itself for color misregistration. Therefore, any over-complication of Klassen would impermissibly modify the principle of operation of the Klassen device. Therefore, one of ordinary skill in the art would not have predictably modified Klassen in the manner the Office Action suggests to render obvious the subject matter of independent claim 8.

b. The Office Action Provides No Objective Evidence To Support Making The Asserted Combination

The Office Action fails to provide any objective evidence of record to support the mere conclusory statement that it would have been obvious to combine Klassen, Decker and Castelli "to avoid any inaccuracies due to the placement of the aperture of the color scanner within a repetitive pattern and to avoid inaccuracies due to density variations caused by variations in the paper velocity through a print station." Fact 11. Because no objective evidence of record has been provided in the Office Action to support the conclusion that it would have been obvious to combine a method for automatic trap selection for correcting for separation misregistration color printing of Klassen with the

system for performing registration calibration for printers by measuring density of Decker and an apparatus for color imagery gloss and registration feedback in a color printing machine as taught in Castelli, the conclusion reached by the Office Action that one of ordinary skill would have predictably modified Klassen in view of Decker and Castelli is unreasonable.

c. The Asserted Basis For Combining The Applied References Is A Mere Conclusory Statement

The Office Action summarily concludes that it would have been obvious to combine Klassen, Decker and Castelli "to avoid any inaccuracies due to the placement of the aperture of the color scanner within a repetitive pattern and to avoid inaccuracies due to density variations caused by variations in the paper velocity through a print station." Fact 12. This is not a reasonable conclusion upon which to base the assertion that one of ordinary skill in the art would have predictably combined any of the teachings of the references, as is suggested by the Office Action, with any reasonable expectation of success in achieving the objectives which are intended to be achieved by, and in the manner of, the subject matter of the pending claims. In fact, there is nothing in Klassen that can reasonably be considered to have suggested that there would be any inaccuracies due to the placement of the aperture of the color scanner within a repetitive pattern and to avoid inaccuracies due to density variations caused by variations in the paper velocity through a print station.

The Office Action fails to provide any support for the mere conclusory statement regarding making the asserted combination of references. It would not have been obvious to combine a method for automatic trap selection for correcting for separation misregistration color printing of Klassen with the system for performing registration calibration for printers by measuring density of Decker and an apparatus for color imagery gloss and registration feedback in a color printing machine as taught in Castelli. To any extent that Klassen teaches avoiding any inaccuracies due to placement of the aperture of the color scanner within a repetitive pattern and avoiding inaccuracies due to density variations caused by variations in the paper velocity through a print station, which Appellants do not concede, this is not a reasonable conclusion upon which to base the assertion that one of ordinary skill in the art would have predictably combined any of the teachings of the references as is suggested by the Office Action with any reasonable expectation of success in achieving the objectives which are intended to be achieved by, and in the manner of, the subject matter of the pending claims. There is no suggestion in Klassen that would support the Office Action's reasoning has no rational underpinning to justify the Office Action's conclusions.

Even after the Supreme Court's decision in *KSR International Co. v. Teleflex Inc.*, 550 US 398, 127 S.Ct. 1727 (2007), the analysis supporting an obviousness rejection must be explicit. The Supreme Court in *KSR* approved

the conclusion set forth in the decision of the Federal Circuit in *In re Kahn*, 441 F.3d 977 (Fed. Cir. 2006), that "rejections on obviousness grounds cannot be sustained by mere conclusory statements; instead the must be some articulated reasoning with some rational underpinning to support the legal conclusion of obviousness." 550 US 398, 127 S.Ct. 1727. The standard is not met here with the mere conclusory statement that one of ordinary skill in the art may have combined the currently-applied references "to avoid any inaccuracies due to the placement of the aperture of the color scanner within a repetitive pattern and to avoid inaccuracies due to density variations caused by variations in the paper velocity through a print station." Fact 11. In other words, there is no rational underpinning to the articulated reasoning.

* * * * *

Accordingly, no predictability has been shown in the Office Action to making the asserted combination of references. For at least this reason, the references are not combinable in the manner suggested, and the rejection based on the combination of these references necessarily fails.

3. <u>Claim 20</u>

Klassen, Decker and Castelli would not have been predictably combined in the manner the Office Action suggests with any reasonable expectation of success at least because the asserted combination of applied references would

impermissibly modify the principle of operation of, and overly complicate, the Klassen device.

Claim 20 recites an apparatus comprising: means for forming images; means for creating at least one registration patch having a combined color value; means for performing spectrophotometric analysis on the at least one registration patch to detect a detected color value; means for determining if color misregistration has occurred on images formed by the means for forming images by comparing the detected color value to the combined color value; means for adjusting an image forming process to adjust for the color misregistration; and means for obtaining a degree of color misregistration based on known dimensions of the registration patch and an amount of color shift that is represented by a ΔE color difference, between the detected color value and the combined color value. Fact 6.

The Office Action asserts that Klassen can reasonably be considered to teach many of the features positively recited in independent claim 20. The Office Action concedes that Klassen fails to disclose forming a registration patch with the image forming system and obtaining a degree of color misregistration based on known dimensions of the registration patch. Fact 7. Rather, the Office Action relies on Decker and Castelli as allegedly making up for this shortfall in the application of Klassen to the subject matter of the pending claims. Fact 8. The Office Action concludes that it would have been obvious to one of ordinary

skill in the art at the time the invention was made to modify the input image of Klassen to be printed as a registration pattern as taught by Decker on a registration patch as taught by Castelli. Fact 11.

The Office Action asserts that one of ordinary skill in the art at the time the invention was made would have predictably modified the input image of Klassen to be printed as a registration pattern as taught by Decker on a registration patch as taught by Castelli with a specified dimension large enough to give an accurate assessment of overall misregistration, but small enough to fit the aperture of a color scanner, to avoid any inaccuracies due to the placement of the aperture of the color scanner within a repetitive pattern, and to avoid inaccuracies due to density variations caused by variations in the paper velocity through a print station. Fact 11. The analysis of the Office Action fails for at least the following reason.

a. The Asserted Combination Would Impermissibly Modify The Principle Of Operation of Klassen

Klassen is directed to a color printing system that deposits colors on a separation-by-separation basis that is calibrated to determine a printed color responsive to a requested color, based on a mapping of device independent colors to printer output colors. Fact 15. The Klassen system provides trapping to correct misregistration between printer output colors due to imperfect placement of the separation color. Fact 16. Klassen teaches that a visibility vector is constructed from two colors (A, B) and a list of misregistration colors,

and a list of values is built which correspond to the visibilities of all of the misregistration colors. Fact 21. Klassen teaches that if the maximum entry in the visibility vector is less than a threshold value T, the misregistration will not be visible, and no action is taken for these two colors, and the next set of two colors is reviewed. Fact 20. Klassen further teaches that an electronic representation of a document from an image input terminal such as a scanner is derived in a format related to the physical characteristics of the device, and commonly with pixels defined at m bits per pixel. Fact 21. In considering the visibility of potential misregistrations, and in creating the visibility vector for the difference in color variation of colors A and B, Klassen bases these calculations on the actual scanned image rather than a registration patch or registration pattern. Fact 22.

By contrast, Decker teaches a system, method, program and print pattern that allows print misregistration to be detected and controlled through density measurements, not variation in colors. Fact 23.

Castelli is directed to a method and apparatus for measuring colormetric, gloss and registration data on a substrate exiting a printing machine. Fact 25. Castelli teaches that a number of color patches are printed using toners from the target printer family using a printer representative of that family, and the color of the patches are selected so as to adequately represent the volume and surface of the printer's color gamut. Fact 26. Castelli further teaches incorporating a

third detector for determining a registration value between a plurality of color separations in the image and generating a signal indicative thereof. Fact 27.

Combining the applied references in the manner asserted would impermissibly modify the principle of operation of, and overly complicate, the Klassen device. There is nothing in Klassen to suggest that Klassen lacks any element that would be necessary to make the color printing system of Klassen "more accurate" such as incorporating the features of Decker and Castelli in the manner the Office Action suggests. Fact 11. Further, incorporating the features of Decker and Castelli into the Klassen device would overly complicate the Klassen device by including the additional functions, such as forming a registration patch, as opposed to merely scanning the image itself for color misregistration. Therefore, any over-complication of Klassen would impermissibly modify the principle of operation of the Klassen device. Therefore, one of ordinary skill in the art would not have predictably modified Klassen in the manner the Office Action suggests to render obvious the subject matter of independent claim 20.

b. The Office Action Provides No Objective Evidence To Support Making The Asserted Combination

The Office Action fails to provide any objective evidence of record to support the mere conclusory statement that it would have been obvious to combine Klassen, Decker and Castelli "to avoid any inaccuracies due to the placement of the aperture of the color scanner within a repetitive pattern and to

avoid inaccuracies due to density variations caused by variations in the paper velocity through a print station." Fact 11. Because no objective evidence of record has been provided in the Office Action to support the conclusion that it would have been obvious to combine a method for automatic trap selection for correcting for separation misregistration color printing of Klassen with the system for performing registration calibration for printers by measuring density of Decker and an apparatus for color imagery gloss and registration feedback in a color printing machine as taught in Castelli, the conclusion reached by the Office Action that one of ordinary skill would have predictably modified Klassen in view of Decker and Castelli is unreasonable.

c. The Asserted Basis For Combining The Applied References Is A Mere Conclusory Statement

The Office Action summarily concludes that it would have been obvious to combine Klassen, Decker and Castelli "to avoid any inaccuracies due to the placement of the aperture of the color scanner within a repetitive pattern and to avoid inaccuracies due to density variations caused by variations in the paper velocity through a print station." Fact 12. This is not a reasonable conclusion upon which to base the assertion that one of ordinary skill in the art would have predictably combined any of the teachings of the references, as is suggested by the Office Action, with any reasonable expectation of success in achieving the objectives which are intended to be achieved by, and in the manner of, the subject matter of the pending claims. In fact, there is nothing in Klassen that

can reasonably be considered to have suggested that there would be any inaccuracies due to the placement of the aperture of the color scanner within a repetitive pattern and to avoid inaccuracies due to density variations caused by variations in the paper velocity through a print station.

The Office Action fails to provide any support for the mere conclusory statement regarding making the asserted combination of references. It would not have been obvious to combine a method for automatic trap selection for correcting for separation misregistration color printing of Klassen with the system for performing registration calibration for printers by measuring density of Decker and an apparatus for color imagery gloss and registration feedback in a color printing machine as taught in Castelli. To any extent that Klassen teaches avoiding any inaccuracies due to placement of the aperture of the color scanner within a repetitive pattern and avoiding inaccuracies due to density variations caused by variations in the paper velocity through a print station, which Appellants do not concede, this is not a reasonable conclusion upon which to base the assertion that one of ordinary skill in the art would have predictably combined any of the teachings of the references as is suggested by the Office Action with any reasonable expectation of success in achieving the objectives which are intended to be achieved by, and in the manner of, the subject matter of the pending claims. There is no suggestion in Klassen that

would support the Office Action's reasoning has no rational underpinning to justify the Office Action's conclusions.

Even after the Supreme Court's decision in *KSR International Co. v. Teleflex Inc.*, 550 US 398, 127 S.Ct. 1727 (2007), the analysis supporting an obviousness rejection must be explicit. The Supreme Court in *KSR* approved the conclusion set forth in the decision of the Federal Circuit in *In re Kahn*, 441 F.3d 977 (Fed. Cir. 2006), that "rejections on obviousness grounds cannot be sustained by mere conclusory statements; instead the must be some articulated reasoning with some rational underpinning to support the legal conclusion of obviousness." 550 US 398, 127 S.Ct. 1727. The standard is not met here with the mere conclusory statement that one of ordinary skill in the art may have combined the currently-applied references "to avoid any inaccuracies due to the placement of the aperture of the color scanner within a repetitive pattern and to avoid inaccuracies due to density variations caused by variations in the paper velocity through a print station." Fact 11. In other words, there is no rational underpinning to the articulated reasoning.

* * * * *

Accordingly, no predictability has been shown in the Office Action to making the asserted combination of references. For at least this reason, the references are not combinable in the manner suggested, and the rejection based on the combination of these references necessarily fails.

B. The Conclusions Made In The Office Action May Only Be Reached Through The Impermissible Application Of Hindsight Reasoning

The Office Action merely concludes that it would have been obvious to combine Klassen with Decker and Castelli to avoid any inaccuracies due to the placement of the aperture of the color scanner within a repetitive pattern and to avoid inaccuracies due to the density variations caused by variations caused by variations in the paper velocity through a print station and to correctly measure the optical densities of the registration patterns. Facts 11 and 13. This conclusion may only be reached through the impermissible application of hindsight reasoning based on the road map provided by Applicants' disclosure.

MPEP §2142 instructs that the proper standard by which to determine obviousness requires (i) that the Examiner step backward in time into the shoes of the hypothetical "person of ordinary skill in the art," (2) that "[i]n view of all the factual information, the Examiner must then make a determination whether the claimed invention 'as a whole' would have been obvious at the time to that person," and (3) that any knowledge gained from Applicants' disclosure must be put aside at reaching this determination in order to avoid the tendency to resort to the impermissible application of hindsight reasoning based on the road map provided by Applicants' disclosure. Clearly, there is nothing in Klassen, Decker and/or Castelli to suggest that one of ordinary skill in the art at the time of invention may have, in any way, predictably combined Klassen with Decker

and Castelli in the manner suggested by the Office Action, and such has not been adequately shown. Fact 16. As such, the only reasonable conclusion that can be arrived at regarding the applied combination is that it is based on the teachings of Applicants' disclosure. Court precedent tells us that it is clearly improper to use the Applicants' teachings against him or her. See, e.g., *In re Sponnoble*, 405 F.2d 578, 585 160 USPQ 237, 234 (CCPA 1969) noting that "in making its determination a court must view the prior art without reading into that art the patent teaches."

C. The Dependent Claims Would Not Have Been Rendered Obvious By The Applied References For The Additional Features They Recite

Dependent claims 2-7 and 9-19 would also not have been rendered obvious by the applied references. No reasonable interpretation of Klassen, Decker, Castelli or the application of official notice (see Fact 28) make up for the above-identified shortfalls in the Office Action's reasoning with respect to the combination of the currently-applied references. Facts 3 and 5. Accordingly, these claims are allowable for at least the respective dependence of these claims on allowable base claims, as well as for the separately patentable subject matter that each of these claims recites.

X. CONCLUSION

For all of the reasons discussed above, it is respectfully submitted that the rejections are in error as to claims 1, 8 and 20, and also therefore in error as to each of the claims depending therefrom. Claims 1-20 are in condition for allowance. For all the above reasons, Appellants respectfully request that this Honorable Board reverse the rejections of claims 1-20.

Respectfully submitted,

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Filed: March 3, 2009

APPENDIX A - CLAIMS APPENDIX

CLAIMS INVOLVED IN THE APPEAL:

1. (Rejected) A method for detecting color misregistration in an image forming system comprising:

forming a registration patch with the image forming system on a recording medium;

calculating or selecting a combined color value for the registration patch;

performing spectrophotometric analysis on the registration patch to detect a detected color value;

determining if color misregistration has occurred by comparing the detected color value with the combined color value; and

obtaining a degree of color misregistration based on known dimensions of the registration patch and an amount of color shift that is represented by a ΔE color difference, between the detected color value and the combined color value.

2. (Rejected) The method for detecting color misregistration according to claim 1, the forming a registration patch further comprising:

forming the registration patch in a combination of colors having a composite color value equivalent to the calculated or selected color value.

3. (Rejected) The method for detecting color misregistration according to claim 1, further comprising generating an output signal in response to determining if color misregistration has occurred.

4. (Rejected) The method for detecting color misregistration according to claim 3, wherein the output signal indicates whether the image forming system is performing within satisfactory limits.

5. (Rejected) The method for detecting color misregistration according to claim 1, the performing spectrophotometric analysis further comprising scanning the registration patch with a spectrophotometric device.

6. (Rejected) The method for detecting color misregistration according to claim 1, wherein the forming a registration patch comprises forming a registration patch which has at least two superimposed colors formed in a line perpendicular to a direction of color misregistration.

7. (Rejected) The method for detecting color misregistration according to claim 1, further comprising performing an adjustment operation if it is determined that an unacceptable level of color misregistration has occurred.

8. (Rejected) An image forming system capable of detecting and adjusting for color misregistration comprising:

a plurality of image forming stations, each image forming station forming an image in one color;

a charge retentive surface which receives each image from its corresponding image forming station and transfers the combined image to a recording medium as a registration patch;

a spectrophotometric device either attached to or integral to the image forming system; and

a controller that causes the spectrophotometric device to perform detection of color misregistration based on known dimensions of the registration patch and an amount of color shift that is represented by a ΔE color difference, on at least one registration patch by comparing a detected color value of the registration patch that is detected by the spectrophotometric device to a combined color value of the registration patch that is calculated or selected.

9. (Rejected) The system of claim 8, wherein the controller further implements an adjustment to reduce detected misregistration.

10. (Rejected) The system of claim 9, wherein the image forming system is a digital photocopier.

11. (Rejected) The system of claim 9, wherein the image forming system is an ink jet printer.

12. (Rejected) The system of claim 9, wherein the image forming system is a laser printer.

13. (Rejected) The system of claim 9, wherein the image forming system is one of a facsimile machine and a combination facsimile machine and printer machine.

14. (Rejected) The image forming system according to claim 9, wherein the registration patch is formed in a combination of colors having a composite color value equivalent to the combined color value.

15. (Rejected) The image forming system according to claim 9, further comprising an output signal which indicates results of the detection of the color misregistration.

16. (Rejected) The image forming system according to claim 15, wherein the output signal indicates whether the image forming system is performing within satisfactory limits.

17. (Rejected) The image forming system according to claim 9, wherein the image forming system performs spectrophotometric analysis, the spectrophotometric analysis comprising:

scanning the registration patch with the spectrophotometric device; and

obtaining a degree of color misregistration between the detected color value detected by the spectrophotometric device and the combined color value.

18. (Rejected) The image forming system according to claim 9, wherein the registration patch comprises at least two superimposed colors formed in a line perpendicular to a direction of color misregistration.

19. (Rejected) The image forming system according to claim 9, further comprising at least one adjustment operation, wherein the adjustment operation is able to alter an image forming process of at least one of the plurality of image forming stations if a spectrophotometric analysis indicates that color misregistration has occurred.

20. (Rejected) An apparatus comprising:

means for forming images on a recording medium;

means for creating at least one registration patch having a combined color value;

means for performing spectrophotometric analysis on the at least one registration patch to detect a detected color value;

means for determining if color misregistration has occurred on images formed by the means for forming images by comparing the detected color value to the combined color value;

means for adjusting an image forming process to adjust for the color misregistration; and

means for obtaining a degree of color misregistration based on known dimensions of the registration patch and an amount of color shift that is

represented by a ΔE color difference, between the detected color value and the combined color value.

APPENDIX B - CLAIM SUPPORT AND DRAWING ANALYSIS SECTION

1. A method for detecting color misregistration in an image forming system comprising {paragraph [0031], Fig. 2, S100-S180}:

forming a registration patch with the image forming system on a recording medium {paragraph [0033], Fig. 2, S130};

calculating or selecting a combined color value for the registration patch {paragraph [0032], Fig. 2, S120};

performing spectrophotometric analysis on the registration patch to detect a detected color value {paragraph [0035], Fig. 2, S140};

determining if color misregistration has occurred by comparing the detected color value with the combined color value {paragraph [0038], Fig. 2, S150}; and

obtaining a degree of color misregistration based on known dimensions of the registration patch and an amount of color shift that is represented by a ΔE color difference, between the detected color value and the combined color value {paragraph [0043], Fig. 7}.

8. An image forming system capable of detecting and adjusting for color misregistration comprising {paragraph [0027], Fig. 1}:

a plurality of image forming stations, each image forming station forming an image in one color {paragraph [0027], Fig. 1, 130, 140, 150, 160};

a charge retentive surface which receives each image from its corresponding image forming station and transfers the combined image to a recording medium as a registration patch {paragraph [0027], Fig. 1, 105};

a spectrophotometric device either attached to or integral to the image forming system {paragraph [0048], Fig. 8, 220}; and

a controller {paragraph [0048], Fig. 8, 250}that causes the spectrophotometric device to perform detection of color misregistration based on known dimensions of the registration patch and an amount of color shift that is represented by a ΔE color difference, on at least one registration patch by comparing a detected color value of the registration patch that is detected by the spectrophotometric device to a combined color value of the registration patch that is calculated or selected {paragraph [0043], Fig. 7}.

20. An apparatus comprising:

means for forming images on a recording medium {paragraph [0027], Fig. 1, 130};

means for creating at least one registration patch having a combined color value {paragraph [0027], Fig. 1, 105};

means for performing spectrophotometric analysis on the at least one registration patch to detect a detected color value {paragraph [0048], Fig. 8, 220};

means for determining if color misregistration has occurred on images formed by the means for forming images by comparing the detected color value to the combined color value {paragraph [0038], Fig. 2, 150};

means for adjusting an image forming process to adjust for the color misregistration {paragraph [0040], Fig. 7, S170}; and

means for obtaining a degree of color misregistration based on known dimensions of the registration patch and an amount of color shift that is represented by a ΔE color difference, between the detected color value and the combined color value {paragraph [0043], Fig. 7}.

APPENDIX C - RELATED PROCEEDINGS APPENDIX

Copies of relevant decisions in the following related proceedings are attached:

NONE

APPENDIX D -EVIDENCE SECTION

A copy of each of the following items of evidence relied on by the Appellant and the Examiner is this appeal is attached.

Table of Contents

Amendment, filed August 12, 2008	Attachment A
Amendment After Final Rejection, filed December 2, 2008	Attachment B
Office Action, mailed October 20, 2008	Attachment C
U.S. Patent No. 6,345,117	Attachment D
U.S. Patent No. 6,198,549	Attachment E
U.S. Patent No. 5,748, 221	Attachment F

APPENDIX E -RELATED CASES

NONE

PATENT APPLICATION

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re the Application of

Paul M. BUTTERFIELD et al.	Group Art Unit: 2625
Application No.: 10/758,099	Examiner: R. ZHU
Filed: January 16, 2004	Docket No.: 117435

For: SYSTEMS AND METHODS FOR SPECTROPHOTOMETRIC ASSESSMENT OF COLOR MISREGISTRATION IN AN IMAGE FORMING SYSTEM

AMENDMENT

Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

Sir:

In reply to the May 27, 2008 Office Action, please consider the following:

Amendments to the Claims as reflected in the listing of claims; and

Remarks.

Attachment A

Amendments to the Claims:

The following listing of claims will replace all prior versions, and listings, of claims in the application:

1. (Currently Amended) A method for detecting color misregistration in an image forming system comprising:

forming a registration patch with the image forming system;

calculating or selecting a combined color value for the registration patch;

performing spectrophotometric analysis on the registration patch to detect a detected color value;

determining if color misregistration has occurred by comparing the detected color value with the combined color value; and

obtaining a degree of color misregistration based on known dimensions of the registration patch and an amount of color shift <u>that is represented by a ΔE color difference,</u> between the detected color value and the combined color value.

2. (Previously Presented) The method for detecting color misregistration according to claim 1, the forming a registration patch further comprising:

forming the registration patch in a combination of colors having a composite color value equivalent to the calculated or selected color value.

3. (Previously Presented) The method for detecting color misregistration according to claim 1, further comprising generating an output signal in response to determining if color misregistration has occurred.

4. (Previously Presented) The method for detecting color misregistration according to claim 3, wherein the output signal indicates whether the image forming system is performing within satisfactory limits.

5. (Previously Presented) The method for detecting color misregistration according to claim 1, the performing spectrophotometric analysis further comprising scanning the registration patch with a spectrophotometric device.

6. (Previously Presented) The method for detecting color misregistration according to claim 1, wherein the forming a registration patch comprises forming a registration patch which has at least two superimposed colors formed in a line perpendicular to a direction of color misregistration.

7. (Original) The method for detecting color misregistration according to claim 1, further comprising performing an adjustment operation if it is determined that an unacceptable level of color misregistration has occurred.

8. (Currently Amended) An image forming system capable of detecting and adjusting for color misregistration comprising:

a plurality of image forming stations, each image forming station forming an image in one color;

a charge retentive surface which receives each image from its corresponding image forming station and transfers the combined image to a recording medium;

a spectrophotometric device either attached to or integral to the image forming system; and

a controller that causes the spectrophotometric device to perform detection of color misregistration <u>based on known dimensions of the registration patch and an amount of color shift that is represented by a ΔE color difference,</u> on at least one registration patch by comparing a detected color value of the registration patch that is detected by the spectrophotometric device to a combined color value of the registration patch that is calculated or selected.

9. (Original) The system of claim 8, wherein the controller further implements an adjustment to reduce detected misregistration.

10. (Original) The system of claim 9, wherein the image forming system is a digital photocopier.

11. (Original) The system of claim 9, wherein the image forming system is an ink jet printer.

12. (Original) The system of claim 9, wherein the image forming system is a laser printer.

13. (Original) The system of claim 9, wherein the image forming system is one of a facsimile machine and a combination facsimile machine and printer machine.

14. (Previously Presented) The image forming system according to claim 9, wherein the registration patch is formed in a combination of colors having a composite color value equivalent to the combined color value.

15. (Previously Presented) The image forming system according to claim 9, further comprising an output signal which indicates results of the detection of the color misregistration.

16. (Original) The image forming system according to claim 15, wherein the output signal indicates whether the image forming system is performing within satisfactory limits.

17. (Currently Amended) The image forming system according to claim 9, wherein the image forming system performs spectrophotometric analysis, the spectrophotometric analysis comprising:

scanning the registration patch with the spectrophotometric device; and

obtaining a degree of color misregistration ~~based on known dimensions of the registration patch and an amount of color shift~~ between the detected color value detected by the spectrophotometric device and the combined color value.

18. (Previously Presented) The image forming system according to claim 9, wherein the registration patch comprises at least two superimposed colors formed in a line perpendicular to a direction of color misregistration.

19. (Previously Presented) The image forming system according to claim 9, further comprising at least one adjustment operation, wherein the adjustment operation is able to alter an image forming process of at least one of the plurality of image forming stations if a spectrophotometric analysis indicates that color misregistration has occurred.

20. (Currently Amended) An apparatus comprising:

means for forming images;

means for creating at least one registration patch having a combined color value;

means for performing spectrophotometric analysis on the at least one registration patch to detect a detected color value;

means for determining if color misregistration has occurred on images formed by the means for forming images by comparing the detected color value to the combined color value;

means for adjusting an image forming process to adjust for the color misregistration; and

means for obtaining a degree of color misregistration based on known dimensions of the registration patch and an amount of color shift <u>that is represented by a ΔE color difference,</u> between the detected color value and the combined color value.

REMARKS

Claims 1-20 are pending. By this Amendment, claims 1, 8, 17 and 20 are amended. Support for the amendments to claims 1, 8, 17 and 20 can be found at least at Fig. 7, for example. No new matter is added.

The Office Action rejects claims 1-9 and 14-20 under 35 U.S.C. §103(a) as being unpatentable over Decker (U.S. Patent No. 6,198,549) in view of Castelli (U.S. Patent No. 5,748,221) and claims 10-13 under 35 U.S.C. §103(a) as being unpatentable over Decker and Castelli in view of Official Notice. These rejections are respectfully traversed.

Applicants respectfully submit that Decker and Castelli, either alone or in combination, do not disclose or suggest at least obtaining a degree of color misregistration based on known dimensions of the registration patch and an amount of color shift, <u>that is represented by a ΔE color difference</u>, between the detected color value and the combined color value, as recited in independent claim 1 and similarly recited in independent claims 8 and 20.

Referring to Decker, there is disclosed a method for detecting print misregistration "by measuring density values using an optical densometer." See col. 2, lines 28-30 of the specification. The <u>optical density</u> of a second repeating pattern is subtracted from the <u>optical density</u> of a first repeating pattern to obtain a <u>density difference</u> for each incremental amount of misregistration. See col. 3, lines 4-9. Decker further discloses that "the misregistration is equal to a constant times the density difference" (misregistration = C_1*(density difference, where C_1 is a constant)). See col. 8, lines 31-33.

As is clear from the above description, Decker only discloses calculating a misregistration that is merely a linear scaling of a density difference. Specifically, the densometer device used to obtain misregistration, as taught by Decker, cannot be used to measure <u>color differences</u>. It is notoriously well known in the art that a densometer can only

measure the degree of darkness, or optical density, of process colors. Thus, Applicant's assert that a densometer is a "color blind" device. Accordingly, Decker does not, and cannot be modified to, disclose obtaining a degree of color misregistration based on an amount of color shift, that is represented by a ΔE color difference.

Castelli does not make up for the above-noted deficiencies of Decker. Specifically, Castelli does not disclose or suggest obtaining a degree of color misregistration based on known dimensions of the registration patch and an amount of color shift, that is represented by a ΔE color difference, between the detected color value and the combined color value, as recited in independent claim 1 and similarly recited in independent claims 8 and 20.

Therefore, Applicants respectfully submit that Decker and Castelli, either alone or in combination, do not disclose or suggest the subject matter recited in the claims. Accordingly, Applicants respectfully submit that claims 1-20 are allowable. Accordingly, Applicants respectfully request withdrawal of the rejection of claims 1-20 under 35 U.S.C. §103(a).

In view of the foregoing, it is respectfully submitted that this application is in condition for allowance. Favorable reconsideration and prompt allowance of claims 1-20 are earnestly solicited.

Should the Examiner believe that anything further would be desirable in order to place this application in even better condition for allowance, the Examiner is invited to contact the undersigned at the telephone number set forth below.

Respectfully submitted,

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Registration No. 42,719

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Date: August 12, 2008

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PATENT APPLICATION

RESPONSE UNDER 37 CFR §1.116
EXPEDITED PROCEDURE
TECHNOLOGY CENTER ART UNIT 2625

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re the Application of

Paul M. BUTTERFIELD et al.	Group Art Unit: 2625
Application No.: 10/758,099	Examiner: R. ZHU
Filed: January 16, 2004	Docket No.: 117435

For: SYSTEMS AND METHODS FOR SPECTROPHOTOMETRIC ASSESSMENT OF COLOR MISREGISTRATION IN AN IMAGE FORMING SYSTEM

AMENDMENT AFTER FINAL REJECTION UNDER 37 CFR §1.116

Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

Sir:

In reply to the October 20, 2008 Office Action, please consider the following:

Amendments to the Claims as reflected in the listing of claims; and

Remarks.

Attachment B

Amendments to the Claims:

The following listing of claims will replace all prior versions, and listings, of claims in the application:

1. (Currently Amended) A method for detecting color misregistration in an image forming system comprising:

forming a registration patch with the image forming system on a recording medium;

calculating or selecting a combined color value for the registration patch;

performing spectrophotometric analysis on the registration patch to detect a detected color value;

determining if color misregistration has occurred by comparing the detected color value with the combined color value; and

obtaining a degree of color misregistration based on known dimensions of the registration patch and an amount of color shift that is represented by a ΔE color difference, between the detected color value and the combined color value.

2. (Previously Presented) The method for detecting color misregistration according to claim 1, the forming a registration patch further comprising:

forming the registration patch in a combination of colors having a composite color value equivalent to the calculated or selected color value.

3. (Previously Presented) The method for detecting color misregistration according to claim 1, further comprising generating an output signal in response to determining if color misregistration has occurred.

4. (Previously Presented) The method for detecting color misregistration according to claim 3, wherein the output signal indicates whether the image forming system is performing within satisfactory limits.

5. (Previously Presented) The method for detecting color misregistration according to claim 1, the performing spectrophotometric analysis further comprising scanning the registration patch with a spectrophotometric device.

6. (Previously Presented) The method for detecting color misregistration according to claim 1, wherein the forming a registration patch comprises forming a registration patch which has at least two superimposed colors formed in a line perpendicular to a direction of color misregistration.

7. (Original) The method for detecting color misregistration according to claim 1, further comprising performing an adjustment operation if it is determined that an unacceptable level of color misregistration has occurred.

8. (Currently Amended) An image forming system capable of detecting and adjusting for color misregistration comprising:

a plurality of image forming stations, each image forming station forming an image in one color;

a charge retentive surface which receives each image from its corresponding image forming station and transfers the combined image to a recording medium as a registration patch;

a spectrophotometric device either attached to or integral to the image forming system; and

a controller that causes the spectrophotometric device to perform detection of color misregistration based on known dimensions of the registration patch and an amount of color shift that is represented by a ΔE color difference, on at least one registration patch by comparing a detected color value of the registration patch that is detected by the spectrophotometric device to a combined color value of the registration patch that is calculated or selected.

9. (Original) The system of claim 8, wherein the controller further implements an adjustment to reduce detected misregistration.

10. (Original) The system of claim 9, wherein the image forming system is a digital photocopier.

11. (Original) The system of claim 9, wherein the image forming system is an ink jet printer.

12. (Original) The system of claim 9, wherein the image forming system is a laser printer.

13. (Original) The system of claim 9, wherein the image forming system is one of a facsimile machine and a combination facsimile machine and printer machine.

14. (Previously Presented) The image forming system according to claim 9, wherein the registration patch is formed in a combination of colors having a composite color value equivalent to the combined color value.

15. (Previously Presented) The image forming system according to claim 9, further comprising an output signal which indicates results of the detection of the color misregistration.

16. (Original) The image forming system according to claim 15, wherein the output signal indicates whether the image forming system is performing within satisfactory limits.

17. (Previously Presented) The image forming system according to claim 9, wherein the image forming system performs spectrophotometric analysis, the spectrophotometric analysis comprising:

scanning the registration patch with the spectrophotometric device; and

obtaining a degree of color misregistration between the detected color value detected by the spectrophotometric device and the combined color value.

18. (Previously Presented) The image forming system according to claim 9, wherein the registration patch comprises at least two superimposed colors formed in a line perpendicular to a direction of color misregistration.

19. (Previously Presented) The image forming system according to claim 9, further comprising at least one adjustment operation, wherein the adjustment operation is able to alter an image forming process of at least one of the plurality of image forming stations if a spectrophotometric analysis indicates that color misregistration has occurred.

20. (Currently Amended) An apparatus comprising:

means for forming images on a recording medium;

means for creating at least one registration patch having a combined color value;

means for performing spectrophotometric analysis on the at least one registration patch to detect a detected color value;

means for determining if color misregistration has occurred on images formed by the means for forming images by comparing the detected color value to the combined color value;

means for adjusting an image forming process to adjust for the color misregistration; and

means for obtaining a degree of color misregistration based on known dimensions of the registration patch and an amount of color shift that is represented by a ΔE color difference, between the detected color value and the combined color value.

REMARKS

Claims 1-20 are pending. By this Amendment, claims 1, 8 and 20 are amended. Support for the amendments can be found, for example, in at least at Fig. 1. No new matter is added. Reconsideration in view of the foregoing amendments and the following remarks is respectfully requested.

Entry of the amendments is proper under 37 CFR §1.116 because the amendments: (a) place the application in condition for allowance (for the reasons discussed herein) and (b) do not raise any new issue requiring further search and/or consideration (as the amendments amplify issues previously discussed throughout prosecution). The amendments are necessary and were not earlier presented because they are made in response to arguments raised in the final rejection. Entry of the amendments is thus respectfully requested.

The courtesies extended to Applicants' representative by Examiner Zhu at the interview held November 25, 2008, are appreciated. The reasons presented at the interview as warranting favorable action are incorporated into the remarks below, which constitute Applicants' record of the interview.

I. Claims 1-20 Define Patentable Subject Matter

The Office Action rejects claims 1-9 and 14-20 under 35 U.S.C. §103(a) as being unpatentable over Klassen (U.S. Patent No. 6,345,117) in view of Decker (U.S. Patent No. 6,198,549) and Castelli (U.S. Patent No. 5,748,221). The Office Action rejects claims 10-13 under 35 U.S.C. §103(a) under Klassen, Decker, Castelli in view of the Official Notice. Applicants respectfully traverse these rejections.

By this amendment, claim 1 is amended for improved clarity and to expedite prosecution of this application. Claim 1, as amended, now recites forming a registration patch with the image forming system on a recording medium. Claims 2-20 substantively recite similar features.

Klassen, Decker and Castelli, either alone or in combination, do not disclose or suggest "forming a registration patch on a recording medium," and "obtaining a degree of color misregistration based on known dimensions of the registration patch and an amount of color shift, that is represented by a ΔE color difference, between the detected color value and the combined color value," as recited in independent claim 1 and similarly recited in independent claims 8 and 20 (emphasis added).

1. Klassen does not disclose a registration patch

The Office Action acknowledges that Klassen does not disclose or suggest "forming a ... registration patch," as recited by independent claims 1, 8 and 20. Nonetheless, the Office Action asserts Klassen discloses several other claimed features (such as forming, detecting, and comparing the registration patch) by asserting that Klassen discloses these features in other situations. However, divorcing the recited forming, detecting and comparing features from the recited registration patch feature distorts the meaning of the claims. As discussed further below, an integral part of the claimed invention is its ability to form a registration patch and use the patch to detect outputted color values. Since the formation, detection and comparison of the registration patch is an integral component of the claimed features, the Office Action's attempt to apply Klassen to the claimed features by simply removing and/or replacing all references to the "registration patch" is improper.

2. Klassen does not disclose or suggest forming a registration patch.

Klassen does not disclose the forming a registration patch, as recited in independent claim 1, and similarly recited in independent claim 20. The Office Action acknowledges that Klassen does not disclose "forming a ... registration patch," but asserts that Klassen discloses the recited "forming" feature. Specifically, the Office Action asserts that Klassen discloses a method for detecting color misregistration by forming a "registration image."

Klassen discloses "forming a digital representation of a scanned input image." See, col 10, lns. 42-62 of Klassen. However, forming a digital representation of a scanned image merely describes the two steps of what is referred to in the vernacular as <u>scanning</u> an image. Specifically, Klassen discloses the <u>mechanical act</u> of scanning the image, followed by the digital step of "<u>forming</u>" the scanned images in memory.

However, scanning and digitalizing an image to be printed is not the same as <u>forming</u> a registration <u>patch</u>. Furthermore, Klassen does not disclose using the scanned image to <u>evaluate</u> the accuracy or color misregistration of any device. Therefore, Applicants assert the Office Action uses flawed logic to link the scanned image disclosed in Klassen to the recited "<u>forming</u> a ... registration patch". Accordingly, Applicants assert Klassen does not disclose the <u>forming</u> a registration <u>patch</u>, as recited in independent claim 1, and similarly recited in independent claims 8 and 20.

3. <u>Klassen does not disclose detecting a color value from a registration patch</u>.

The Office Action also asserts that Klassen discloses the recited step of "performing spectrophotometric analysis on the registration patch to detect a <u>detected</u> color value." However, as previously discussed, Klassen does not disclose using registration patches and therefore cannot <u>detect</u> outputted color values by analyzing such patches.

Klassen discloses a system that estimates the likelihood of visible distortions by using a color table and printer specific misregistration information. However, Klassen does not <u>detect</u> color values. Rather, Klassen calculates the <u>likelihood</u> of an error occurring and attempts to <u>prevent</u> misregistration. Accordingly, Klassen fails to disclose performing spectrophotometric analysis on the registration patch to detect a <u>detected</u> color value, as recited in independent claim 1, and similarly recited in independent claims 8 and 20.

4. **<u>Klassen does not disclose comparing detected color values</u>.**

The Office Action asserts that Klassen, in col 14 ln. 1-14 discloses "comparing a maximum value of visibility vector with a threshold value to determine whether misregistration occurs." See Office Action, pg. 3-4. However, the cited passage was taken out of context and lacks clarity. The section cited by the examiner more accurately states:

> a Visibilityvector is constructed from two colors (a, b) and the list of misregistration colors, and a list of values is built which correspond to the visibilities of all the misregistration colors. If the maximum entry in the Visibilityvector is less than a threshold value t (FIGS. 4 and 5, step 204), the misregistration will not be visible. No action is taken at these two colors, and the next set of two colors is reviewed.

Thus, the cited section discloses constructing a "Visibilityvector" from two colors that are to be printed (a, b) and a list of known mistregistration colors. From this "Visibilityvector," a list is created corresponding to the likelihood of distortions resulting from overlaying the desired colors (a, b). From analyzing this "Visibilityvector," it is determined whether printing the desired colors (a, b) side-by-side is likely to result in a distortion.

Thus, under Klassen, no <u>actual</u> misregistration is detected. Rather, the <u>likelihood</u> of potential misregistration errors is calculated based on two colors that the system <u>intends</u> to print next to one another. Therefore, Klassen fails to disclose or suggest determining if color misregistration has occurred by <u>comparing</u> the <u>detected</u> color value with the combined color value, as recited in independent claim 1. Accordingly, Applicants assert Klassen fails to disclose any of the above-mentioned features.

5. **<u>Decker and Castelli fail to cure the deficiencies of Klassen.</u>**

Decker simply discloses a method for detecting misregistration "by measuring density values using an optical densometer." See col. 2, lines 28-30. Decker discloses calculating a

misregistration error defined by a linear scaling of a density difference across an image. Thus, the densometer device used to obtain misregistration, as taught by Decker, cannot be used to measure color differences. Accordingly, Decker does not disclose detecting a detected color value and obtaining a degree of color misregistration based on an amount of color shift, that is represented by a ΔE color difference, as recited in independent claim 1, and similarly recited in independent claims 8 and 20.

Castelli does not make up for the above-noted deficiencies of Decker. Castelli does not disclose measuring color values, nor does Castelli disclose or suggest determining if color misregistration has occurred by comparing the detected color value with the combined color value. Rather, Castelli merely discloses detecting if misregistration has occurred by using the chevron mark technology and bi-cell detectors, and simply compares timing patterns of photo diodes. Therefore, Castelli does not disclose or suggest determining if color misregistration has occurred by comparing the detected color value with the combined color value, as recited in independent claim 1 and similarly recited in independent claims 8 and 20.

II. Conclusion

In view of the foregoing, it is respectfully submitted that this application is in condition for allowance. Favorable reconsideration and prompt allowance of claims 1-20 are earnestly solicited.

Should the Examiner believe that anything further would be desirable in order to place this application in even better condition for allowance, the Examiner is invited to contact the undersigned at the telephone number set forth below.

Respectfully submitted,

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JAO:BBM/tbm

Date: December 2, 2008

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Please find below and/or attached an Office communication concerning this application or proceeding.

The time period for reply, if any, is set in the attached communication.

Notice of the Office communication was sent electronically on above-indicated "Notification Date" to the following e-mail address(es):

OfficeAction27074@oliff.com
jarmstrong@oliff.com

FINAL REJECTION/
NOTICE OF APPEAL

DUE DATE
JAN 20 2009

Attachment C

DOCKETED
By Fmp on 10/20 2008
and
By BRJ on Oct 20 2008
Oliff & Berridge

DOCKETED
By Fmp on 10/20 2008
and
By BRJ on Oct 20 2008
Oliff & Berridge

PTOL-90A (Rev. 04/07)

Office Action Summary	Application No. 10/758,099	Applicant(s) BUTTERFIELD ET AL.	
	Examiner RICHARD Z. ZHU	Art Unit 2625	

-- The MAILING DATE of this communication appears on the cover sheet with the correspondence address --

Period for Reply

A SHORTENED STATUTORY PERIOD FOR REPLY IS SET TO EXPIRE _3_ MONTH(S) OR THIRTY (30) DAYS, WHICHEVER IS LONGER, FROM THE MAILING DATE OF THIS COMMUNICATION.

- Extensions of time may be available under the provisions of 37 CFR 1.136(a). In no event, however, may a reply be timely filed after SIX (6) MONTHS from the mailing date of this communication.
- If NO period for reply is specified above, the maximum statutory period will apply and will expire SIX (6) MONTHS from the mailing date of this communication.
- Failure to reply within the set or extended period for reply will, by statute, cause the application to become ABANDONED (35 U.S.C. § 133). Any reply received by the Office later than three months after the mailing date of this communication, even if timely filed, may reduce any earned patent term adjustment. See 37 CFR 1.704(b).

Status

1)☒ Responsive to communication(s) filed on _12 August 2008_.

2a)☒ This action is **FINAL**. 2b)☐ This action is non-final.

3)☐ Since this application is in condition for allowance except for formal matters, prosecution as to the merits is closed in accordance with the practice under *Ex parte Quayle*, 1935 C.D. 11, 453 O.G. 213.

Disposition of Claims

4)☒ Claim(s) _1-20_ is/are pending in the application.

4a) Of the above claim(s) _____ is/are withdrawn from consideration.

5)☐ Claim(s) _____ is/are allowed.

6)☒ Claim(s) _1-20_ is/are rejected.

7)☐ Claim(s) _____ is/are objected to.

8)☐ Claim(s) _____ are subject to restriction and/or election requirement.

Application Papers

9)☐ The specification is objected to by the Examiner.

10)☐ The drawing(s) filed on _____ is/are: a)☐ accepted or b)☐ objected to by the Examiner.

Applicant may not request that any objection to the drawing(s) be held in abeyance. See 37 CFR 1.85(a).

Replacement drawing sheet(s) including the correction is required if the drawing(s) is objected to. See 37 CFR 1.121(d).

11)☐ The oath or declaration is objected to by the Examiner. Note the attached Office Action or form PTO-152.

Priority under 35 U.S.C. § 119

12)☐ Acknowledgment is made of a claim for foreign priority under 35 U.S.C. § 119(a)-(d) or (f).

a)☐ All b)☐ Some * c)☐ None of:

1.☐ Certified copies of the priority documents have been received.

2.☐ Certified copies of the priority documents have been received in Application No. _____.

3.☐ Copies of the certified copies of the priority documents have been received in this National Stage application from the International Bureau (PCT Rule 17.2(a)).

* See the attached detailed Office action for a list of the certified copies not received.

Attachment(s)

1) ☒ Notice of References Cited (PTO-892)

2) ☐ Notice of Draftsperson's Patent Drawing Review (PTO-948)

3) ☒ Information Disclosure Statement(s) (PTO/SB/08) Paper No(s)/Mail Date _06/19/2008_.

4) ☐ Interview Summary (PTO-413) Paper No(s)/Mail Date. _____ .

5) ☐ Notice of Informal Patent Application

6) ☐ Other: _____.

DETAILED ACTION

Acknowledgement

1. Acknowledgement is made of applicant's amendment made on 08/12/2008. Applicant's submission filed has been entered and made of record.

Status of the Claims

2. Claims 1-20 are pending. Claims 1, 8, 17, and 20 are "currently amended".

Response to Applicant's Arguments

3. Applicant amended the claim to require determination of color misregistration on the basis of color shift represented by ΔE color difference. This is defined in the specification as color difference requiring analysis and calculation in CIE-LAB color space, which is different from the color shift of ***Decker***. Therefore, the scope of color shift is now limited to what is defined in the specification. In view of this amendment, rejections set forth in the previous office action are withdrawn. In view of a new reference "***Klassen***" upon further consideration, new grounds of rejections are enter in this office action.

4. Whether or not the densitometer of ***Decker*** precludes ***Decker*** from being modified in the context of the invention is up for debate. However, the relevant teachings of printing registration patterns and patches in ***Decker*** can still be use as a secondary teaching for modifying a primary reference because at least said relevant teachings of the disclosure has nothing to do with any limitations inherent in a densitometer. That is, given the color scanner of ***Klassen***, the new primary reference can be modify by ***Decker*** because the invention of

Klassen can still be printed as registration patterns on registration patches without any teaching directly suggest against it. Therefore, it is proper to modify ***Klassen*** with ***Decker***.

Claim Rejections - 35 USC § 103

5. The following is a quotation of 35 U.S.C. 103(a) which forms the basis for all obviousness rejections set forth in this Office action:

> (a) A patent may not be obtained though the invention is not identically disclosed or described as set forth in section 102 of this title, if the differences between the subject matter sought to be patented and the prior art are such that the subject matter as a whole would have been obvious at the time the invention was made to a person having ordinary skill in the art to which said subject matter pertains. Patentability shall not be negatived by the manner in which the invention was made.

6. Claims 1-9 and 14-20 are rejected under 35 USC 103 (a) as being unpatentable over ***Klassen (US 6345117 B2)*** in view of ***Decker (US 6198549 B1)*** and ***Castelli et al. (US 5748221 A)***.

Regarding Claim 1, *Klassen* discloses a method for detecting color misregistration in an image forming system comprising (**Abstract, detecting and trapping color misregistration and see Fig 3**):

forming a registration image with the image forming system (**Col 10, Rows 42-62, forming a digital representation of a scanned input image**);

calculating or selecting a combined color value (**Col 11-12, Table 1, in particular, the Boolean combination of cyan and magenta "1100", "1101", "1110" and "1111"**);

performing spectrophotometric analysis on the registration patch to detect a detected color value (**Col 10, Rows 41-48, common color scanner 10, see Fig 3 for detecting input colors a and b, see Col 11, Rows 40-50**);

determining if color misregistration has occurred (**Col 14, Rows 1-14, comparing the maximum of a visibility vector with a threshold to determine whether**

misregistration occurs) by comparing the detected color value with the combined color value (**Col 13, Row 66- Col 14, Row 2, said visibility vector is constructed from the two colors a and b and the list of misregistration colors or combined color value shown in Table 1. That is, the ΔE that representing the difference or comparison between actual input colors (a, b) and list of misregistration colors being used to construct the visibility vector that is used to determine whether or not misregistration is visible**); and

obtaining a degree of color misregistration based on an amount of color shift between the detected color value and the combined color value that is represented by a ΔE color difference between the detected color value and the combined color value (**Col 13, Rows 1-45, as best understood by the examiner, ΔE, be it standard CIE76, CIE94, or S-CIELab, is used to determine whether misregistration is visible, see Col 13, Rows 8-15 and it appears to play a part in deriving the visibility function made from input colors a and b and the list of misregistration colors shown in Table 1. The degree of misregistration is determined by comparing this derived visibility function to a threshold**);

Klassen does not disclose forming a registration patch with the image forming system and obtaining a degree of color misregistration based on known dimensions of the registration patch.

Decker discloses a method for detecting color misregistration in an image forming system (**Abstract**) comprising:

forming a registration pattern with the image forming system (**Fig 2 and see Col 4, Rows 31-34**);

performing spectrophotometric analysis on the registration patch to detect a detected color value (**Co 8, Rows 20-30, using a densitometer to perform spectrophotometric analysis**).

determining if color misregistration has occurred (**Col 5, Row 62- Col 6, Row 8, Col 7, Rows 5-15, and see Col 8, Rows 20-67, the amount of color misregistration – C1 * (Density Difference)**);

obtaining a degree of color misregistration based on known dimensions of the registration pattern (**Col 5, Rows 20-40**).

Castelli discloses a method or detecting color misregistration in an image forming system (**Col 3, Rows 24-30**) comprising forming a registration patch with registration pattern thereon using the image forming system (**Col 6, Rows 65-67**).

Decker suggested that the dimension of a registration pattern must be such that it is large enough for a spectrophotometer such as a colorimeter of ***Castelli*** or color scanner of ***Klassen*** to have an accurate assessment of the average overall misregistration and small enough for said spectrophotometer's aperture, it would've been obvious to one of ordinary skill in the art at the time of the invention to modify the input image of ***Klassen*** to be printed as registration pattern taught by ***Decker*** on a registration patch taught by ***Castelli*** with a specified dimension large enough to give an accurate assessment of overall misregistration but small enough to fit the aperture of color scanner whereas the motivation would've been to avoid any inaccuracies due to the placement of the aperture of the color scanner within a repetitive pattern and to avoid inaccuracies due to density variations caused by variations in the paper velocity though a print station (***Decker*, Col 5, Rows 40-45**).

Regarding Claim 2, ***Klassen*** as modified by ***Decker*** and ***Castelli*** discloses the step of forming a registration patch further comprising steps of:

forming the registration patch in a combination of colors having a composite color value equivalent to the calculated or selected value (***Decker,*** **Col 4, Rows 30-60 and see Col 8, Rows 19-21, colors comprising Cyan, Magenta, Yellow, and Black**).

Regarding Claim 3, ***Klassen*** discloses the method for detecting color misregistration further comprising generating an output signal in response to determining if color misregistration has occurred (**Col 14, Rows 1-14, if the maximum of the visibility function is greater than a predetermined threshold, an output signal indicating visible misregistration is outputted so that a color can be determined and selected for trapping**).

Regarding Claim 4, ***Klassen*** discloses that the output signal indicates whether the image forming system is performing within satisfactory limits (**Col 14, Rows 1-14, if the maximum of the visibility function is less than a predetermined threshold, it is determined that misregistration is not visible and the system is performing satisfactorily**).

Regarding Claims 5, ***Klassen*** as modified by ***Decker*** and ***Castelli*** discloses the method for detecting color misregistration, performing spectrophotometric analysis and the spectrophotometric analysis further comprising:

scanning the registration patch with a spectrophotometric device (***Klassen,*** **Col 10, Rows 42-62, color scanner 10,** ***Decker,*** **Col 8, Rows 24-25, using a densitometer. Said color scanner is modified to scan repetitive patterns**).

Regarding Claims 6, ***Klassen*** as modified by ***Decker*** and ***Castelli*** discloses wherein the forming a registration patch comprises forming a registration patch which has at least two superimposed colors formed in a line perpendicular to a direction of color misregistration (***Decker,*** **Fig 2A-B and see Col 4, Rows 52-67**).

Regarding Claim 7, ***Klassen*** discloses the method for detecting color misregistration further comprising performing an adjustment operation if it is determined that an unacceptable level of color misregistration has occurred (**Col 14, Rows 15-50, see also Col 2, Rows 16-25, using color trapping to correct misregistration**).

Regarding Claim 8, ***Klassen*** discloses an image forming system capable of detecting and adjusting for color misregistration (**Fig 3**) comprising:

a spectrophotometric device either attached to or integral to the image forming system (**Col 10, Rows 41-48, common color scanner 10, see Fig 3**);

a controller that causes the spectrophotometric device to perform detection of color misregistration (**Fig 3, Image Processing Unit 16 as a software in a digital computer realized as either software embodied in a computer hard drive to be executed by CPU or hardware logic circuitry, see Col 18, Rows 20-35**) base on at least an amount of color shift that is represented by a AE color difference, on at least one registration image by comparing a detected color value of the registration patch that is detected by the spectrophotometric device to a combined color value of the registration patch that is calculated or selected (**Col 13, Rows 1-45, as best understood by the examiner, ΔE, be it standard CIE76, CIE94, or S-CIELab, is used to determine whether misregistration is**

visible, see Col 13, Rows 8-15 and it appears to play a part in deriving the visibility function made from input colors a and b and the list of misregistration colors shown in Table 1. The degree of misregistration is determined by comparing this derived visibility function to a threshold).

Klassen does not disclose performing detection of color misregistration based on known dimensions of a registration pattern.

Decker discloses a method for detecting color misregistration in an image forming system (**Abstract**) comprising:

forming a registration pattern with the image forming system (**Fig 2 and see Col 4, Rows 31-34**);

performing spectrophotometric analysis on the registration patch to detect a detected color value (**Co 8, Rows 20-30, using a densitometer to perform spectrophotometric analysis**).

determining if color misregistration has occurred (**Col 5, Row 62- Col 6, Row 8, Col 7, Rows 5-15, and see Col 8, Rows 20-67, the amount of color misregistration – C1 * (Density Difference)**);

obtaining a degree of color misregistration based on known dimensions of the registration pattern (**Col 5, Rows 20-40**).

Decker suggested that the dimension of a registration pattern must be such that it is large enough for a spectrophotometer such as a color scanner of ***Klassen*** to have an accurate assessment of the average overall misregistration and small enough for said spectrophotometer's aperture, it would've been obvious to one of ordinary skill in the art at

the time of the invention to modify the input image of ***Klassen*** to be printed as registration pattern taught by ***Decker*** with a specified dimension large enough to give an accurate assessment of overall misregistration but small enough to fit the aperture of color scanner whereas the motivation would've been to avoid any inaccuracies due to the placement of the aperture of the color scanner within a repetitive pattern and to avoid inaccuracies due to density variations caused by variations in the paper velocity though a print station (***Decker*, Col 5, Rows 40-45**).

The combined teachings do not disclose a plurality of image forming stations, each image forming station forming an image in one color and a charge retentive surface which receives each image from its corresponding image forming station and transfers the combined image to a recording medium.

Castelli discloses an image forming system capable of detecting and adjusting for color misregistration comprising:

a plurality of image forming stations, each image forming station forming an image in one color (***Castelli*, Fig 6, Development Stations C and D**);

a charge retentive surface which receives each image from its corresponding image forming station and transfers the combined image to a recording medium (***Castelli*, Fig. 6, belt 10, and see Col 4, Rows 25-30**);

a spectrophotometric device either attached to or integral to the image forming system (***Castelli*, Col 6, Rows 61-64, spectrophotometer connected via neural networks and Col**

6, Rows 9-16, the main sensor of the invention is integral to the image forming system); and

a controller that causes the spectrophotometric device to perform detection of color misregistration on at least one registration patch (***Castelli*, Fig. 7, Controller**).

Decker suggested in its background arts that it is well known to form test patterns on patches (**Col 1, Rows 14-28**). Therefore, it would've been obvious to one of ordinary skill in the art at the time of the invention to modify the input image of ***Klassen*** to be printed as registration pattern taught by ***Decker*** on a registration patch taught by ***Castelli*** so as to correctly measure the optical densities of said registration patterns (***Decker*, Col 1, Rows 14-28**).

Regarding Claim 9, ***Klassen*** discloses the controller further implements an adjustment to reduce detected misregistration (**Col 14, Rows 36-50, determining out a plurality of candidates, who best implements an adjustment to make misregistration invisible**).

Regarding Claim 14, ***Klassen*** as modified by ***Decker*** and ***Castelli*** discloses the registration patch is formed in a combination of colors having a composite color value equivalent to the combined color value (***Klassen*, Col 13, Row 66 – Col 14, Row 14, the colors comprising any combination of two colors a and b involves a combination of C, M, Y, and K, see Col 14, Rows 20-35**).

Regarding Claims 15 and 16, ***Klassen*** discloses the controller further implements an output signal which indicates the results of the detection of the color misregistration (**Col 14,**

Rows 1-14, if the maximum of the visibility function is greater than a predetermined threshold, an output signal indicating visible misregistration is outputted so that a color can be determined and selected for trapping) and output signal indicates whether the image forming system is performing within satisfactory limits (**Col 14, Rows 1-14, if the maximum of the visibility function is less than a predetermined threshold, it is determined that misregistration is not visible and the system is performing satisfactorily**).

Regarding Claim 17, *Klassen* as modified by ***Decker*** and ***Castelli*** discloses the method for detecting color misregistration, performing spectrophotometric analysis and the spectrophotometric analysis further comprising:

scanning the registration patch with a spectrophotometric device (***Klassen,* Col 10, Rows 42-62, color scanner 10. See also *Decker,* Col 8, Rows 24-25, using a densitometer**);

and obtaining a degree of color misregistration based on an amount of color shift between the color detected by the spectrophotometric device and the calculated or selected color value (***Klassen,* Col 13, Rows 1-45, as best understood by the examiner, ΔE, be it standard CIE76, CIE94, or S-CIELab, is used to determine whether misregistration is visible, see Col 13, Rows 8-15 and it appears to play a part in deriving the visibility function made from input colors a and b and the list of misregistration colors shown in Table 1. The degree of misregistration is determined by comparing this derived visibility function to a threshold**).

Regarding Claims 18, ***Klassen*** as modified by ***Decker*** and ***Castelli*** discloses wherein the forming a registration patch comprises forming a registration patch which has at least two superimposed colors formed in a line perpendicular to a direction of color misregistration (***Decker,*** **Fig 2A-B and see Col 4, Rows 52-67**).

Regarding Claim 19, ***Klassen*** as modified by ***Decker*** and ***Castelli*** discloses at least one adjustment operation wherein the adjustment operation is able to alter an image forming process of at least one of the plurality of image forming stations if a spectrophotometric analysis indicates color misregistration has occurred (***Klassen,*** **Col 14, Rows 15-50, see also Col 2, Rows 16-25, using color trapping as adjustment operation to correct misregistration**).

Regarding Claim 20, ***Klassen*** discloses an apparatus comprising:

means for forming image digitally (**Col 10, Rows 42-62**);

means for performing spectrophotometric analysis on the at least one registration image to detect a detected color value (**Fig 3, Image Processing Unit 16 as a software in a digital computer + Color Scanner 110**);

means for determining if color misregistration has occurred based on the spectrophotometric analysis of the registration image (**Fig 3, Image Processing Unit 16 and see Col 13, Row 66 – Col 14, Row 14**);

means for adjusting the image forming process to adjust for the color misregistration (**Fig 3, Image Processing Unit 16 as a software in a digital computer + Trapping Processor 18**);

means for obtaining a degree of color misregistration based on at least an amount of color shift that is represented by a AE color difference, on at least one registration image by comparing a detected color value of the registration patch that is detected by the spectrophotometric device to a combined color value of the registration patch that is calculated or selected (**Col 13, Rows 1-45, as best understood by the examiner, ΔE, be it standard CIE76, CIE94, or S-CIELab, is used to determine whether misregistration is visible, see Col 13, Rows 8-15 and it appears to play a part in deriving the visibility function made from input colors a and b and the list of misregistration colors shown in Table 1. The degree of misregistration is determined by comparing this derived visibility function to a threshold**).

Klassen does not disclose performing detection of color misregistration based on known dimensions of a registration pattern.

Decker discloses a method for detecting color misregistration in an image forming system (**Abstract**) comprising:

means for forming a registration pattern with the image forming system (**Fig 2 and see Col 4, Rows 31-34**);

means for performing spectrophotometric analysis on the registration patch to detect a detected color value (**Co 8, Rows 20-30, using a densitometer to perform spectrophotometric analysis**).

means for determining if color misregistration has occurred (**Col 5, Row 62- Col 6, Row 8, Col 7, Rows 5-15, and see Col 8, Rows 20-67, the amount of color misregistration – C1 * (Density Difference)**);

means for obtaining a degree of color misregistration based on known dimensions of the registration pattern (**Col 5, Rows 20-40**).

Decker suggested that the dimension of a registration pattern must be such that it is large enough for a spectrophotometer such as a color scanner of ***Klassen*** to have an accurate assessment of the average overall misregistration and small enough for said spectrophotometer's aperture, it would've been obvious to one of ordinary skill in the art at the time of the invention to modify the input image of ***Klassen*** to be printed as registration pattern taught by ***Decker*** with a specified dimension large enough to give an accurate assessment of overall misregistration but small enough to fit the aperture of color scanner whereas the motivation would've been to avoid any inaccuracies due to the placement of the aperture of the color scanner within a repetitive pattern and to avoid inaccuracies due to density variations caused by variations in the paper velocity though a print station (***Decker*, Col 5, Rows 40-45**).

The combined teachings do not disclose means for forming images by creating at least one registration pattern on a patch.

Castelli discloses an apparatus for detecting color misregistration comprising:

means for forming images (**Col 4, Rows 5-7, an imaging system**);

means for creating at least one registration patch (**Col 6, Rows 65-67, a number of patches**) having a combined color value (**Col 6, Row 67 – Col 7, Row 2, colors are selected to adequately represent the printer's collection of colors, a combination of RGB or CMYK**);

Decker suggested in its background arts that it is well known to form test patterns on patches (**Col 1, Rows 14-28**). Therefore, it would've been obvious to one of ordinary skill in the art at the time of the invention to modify the input image of ***Klassen*** to be printed as registration pattern taught by ***Decker*** on a registration patch taught by ***Castelli*** so as to correctly measure the optical densities of said registration patterns ***(Decker,*** **Col 1, Rows 14-28**).

7. Claims 10-13 are rejected under 35 USC 103 (a) as being unpatentable over the combined teachings of ***Klassen (US 6345117 B2)*** in view of ***Decker (US 6198549 B1)*** and ***Castelli et al. (US 5748221 A)*** further in view of what is well known.

Regarding Claims 10-13, the combined teachings do not explicitly disclose that the printing machine is a digital photocopier, an ink jet printer, or a laser printer.

Nonetheless, the cited printing machines are well known species of genus printing machines and it is well within the knowledge of one ordinarily skilled in the art to use the above-mentioned copiers and printers as the image forming system because each of said copiers and printers are qualified to perform superbly in the endeavor of color printing and they are all very well known under the sun (**Official Notice**).

It would've been obvious to one ordinarily skilled in the art at the time of invention to use either a digital photocopier, an ink jet printer, a laser printer, a facsimile machine, or a combination facsimile machine and printer machine as the printing machine of the combined teachings in order to enable the printing of multi-color images from which spectrophotometric analysis can be performed.

Conclusion

8. Applicant's amendment necessitated the new grounds of rejection presented in this Office action. Accordingly, **THIS ACTION IS MADE FINAL**. See MPEP § 706.07(a). Applicant is reminded of the extension of time policy as set forth in 37 CFR 1.136(a).

A shortened statutory period for reply to this final action is set to expire THREE MONTHS from the mailing date of this action. In the event a first reply is filed within TWO MONTHS of the mailing date of this final action and the advisory action is not mailed until after the end of the THREE-MONTH shortened statutory period, then the shortened statutory period will expire on the date the advisory action is mailed, and any extension fee pursuant to 37 CFR 1.136(a) will be calculated from the mailing date of the advisory action. In no event, however, will the statutory period for reply expire later than SIX MONTHS from the mailing date of this final action.

Any inquiry concerning this communication or earlier communications from the examiner should be directed to examiner Richard Z. Zhu whose telephone number is 571-270-1587 or examiner's supervisor King Y. Poon whose telephone number is 571-272-7440. Examiner Richard Zhu can normally be reached on Monday through Thursday, 6:30 - 5:00.

Information regarding the status of an application may be obtained from the Patent Application Information Retrieval (PAIR) system. Status information for published applications may be obtained from either Private PAIR or Public PAIR. Status information for unpublished applications is available through Private PAIR only. For more information about the PAIR system, see http://pair-direct.uspto.gov. Should you have questions on access to the Private PAIR system, contact the Electronic Business Center (EBC) at 866-217-9197

(toll-free). If you would like assistance from a USPTO Customer Service Representative or access to the automated information system, call 800-786-9199 (IN USA OR CANADA) or 571-272-1000.

RZ[2]
10/08/2008

Richard Z. Zhu
Assistant Examiner
Art Unit 2625

/King Y. Poon/

Supervisory Patent Examiner, Art Unit 2625

Notice of References Cited	Application/Control No. 10/758,099	Applicant(s)/Patent Under Reexamination BUTTERFIELD ET AL.	
	Examiner RICHARD Z. ZHU	Art Unit 2625	Page 1 of 1

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*		Document Number Country Code-Number-Kind Code	Date MM-YYYY	Name	Classification
*	A	US-6,345,117 B2	02-2002	Klassen, R. Victor	382/167
*	B	US-6,970,271 B1	11-2005	Estrada et al.	358/1.9
*	C	US-7,193,640 B2	03-2007	Egan, Richard G.	347/171
*	D	US-7,256,910 B2	08-2007	Lee, David L.	358/1.9
	E	US-			
	F	US-			
	G	US-			
	H	US-			
	I	US-			
	J	US-			
	K	US-			
	L	US-			
	M	US-			

FOREIGN PATENT DOCUMENTS

*		Document Number Country Code-Number-Kind Code	Date MM-YYYY	Country	Name	Classification
	N					
	O					
	P					
	Q					
	R					
	S					
	T					

NON-PATENT DOCUMENTS

*		Include as applicable: Author, Title Date, Publisher, Edition or Volume, Pertinent Pages)
	U	
	V	
	W	
	X	

*A copy of this reference is not being furnished with this Office action. (See MPEP § 707.05(a).)
Dates in MM-YYYY format are publication dates. Classifications may be US or foreign.

Index of Claims	Application/Control No. 10758099	Applicant(s)/Patent Under Reexamination BUTTERFIELD ET AL.
	Examiner Zhu, Richard Z	Art Unit 2625

✓	Rejected	-	Cancelled	N	Non-Elected	A	Appeal
=	Allowed	÷	Restricted	I	Interference	O	Objected

☐ Claims renumbered in the same order as presented by applicant ☐ CPA ☐ T.D. ☐ R.1.47

CLAIM		DATE								
Final	Original	04/26/2007	08/01/2007	09/27/2007	02/04/2008	05/19/2008	10/08/2008			
	1	✓	✓	✓	✓	✓	✓			
	2	✓	✓	✓	✓	✓	✓			
	3	✓	✓	✓	✓	✓	✓			
	4	✓	✓	✓	✓	✓	✓			
	5	✓	✓	✓	✓	✓	✓			
	6	✓	✓	✓	✓	✓	✓			
	7	✓	✓	✓	✓	✓	✓			
	8	✓	✓	✓	✓	✓	✓			
	9	✓	✓	✓	✓	✓	✓			
	10	✓	✓	✓	✓	✓	✓			
	11	✓	✓	✓	✓	✓	✓			
	12	✓	✓	✓	✓	✓	✓			
	13	✓	✓	✓	✓	✓	✓			
	14	✓	✓	✓	✓	✓	✓			
	15	✓	✓	✓	✓	✓	✓			
	16	✓	✓	✓	✓	✓	✓			
	17	✓	✓	✓	✓	✓	✓			
	18	✓	✓	✓	✓	✓	✓			
	19	✓	✓	✓	✓	✓	✓			
	20	✓	✓	✓	✓	✓	✓			

Search Notes	Application/Control No.	Applicant(s)/Patent Under Reexamination
	10758099	BUTTERFIELD ET AL.
	Examiner	**Art Unit**
	Zhu, Richard Z	2625

SEARCHED

Class	Subclass	Date	Examiner
358	1.9, 3.26, 504	8/1/2007	RZ
347	116	8/1/2007	RZ
356	319	8/1/2007	RZ
399	301	8/1/2007	RZ
356	402, 419, 425	9/27/2007	RZ
358	1.9, 3.26, 3.27, 1.14, 501, 504, 515, 519	5/19/2008	RZ

SEARCH NOTES

Search Notes	Date	Examiner
East Database Class and Keyword Limited Search, See East Search History	4/26/2007	RZ
East Inventor Name Search, See East Search History	4/26/2007	RZ
East Database Class and Keyword Limited Search, See East Search History	8/1/2007	RZ
East Database Class and Keyword Limited Search, See East Search History	9/27/2007	RZ
East Database Class and Keyword Limited Search, See East Search History	2/4/2008	RZ
East Database Class and Keyword Limited Search, See East Search History	5/19/2008	RZ
East Database Class and Keyword Limited Search, See East Search History	10/08/2008	RZ

INTERFERENCE SEARCH

Class	Subclass	Date	Examiner

/RICHARD Z ZHU/ Examiner.Art Unit 2625	

EAST Search History

Ref #	Hits	Search Query	DBs	Default Operator	Plurals	Time Stamp
L1	1	"20020135629".pn.	US-PGPUB; USPAT; USOCR	OR	OFF	2008/10/08 13:04
S84	6158	358/1.9.ccls.	US-PGPUB; USPAT; USOCR; DERWENT	OR	ON	2008/09/22 09:04
S85	876	358/3.26.ccls.	US-PGPUB; USPAT; USOCR; DERWENT	OR	ON	2008/09/22 09:04
S86	582	358/3.27.ccls.	US-PGPUB; USPAT; USOCR; DERWENT	OR	ON	2008/09/22 09:04
S87	2200	358/1.14.ccls.	US-PGPUB; USPAT; USOCR; DERWENT	OR	ON	2008/09/22 09:04
S88	456	358/501.ccls.	US-PGPUB; USPAT; USOCR; DERWENT	OR	ON	2008/09/22 09:04
S89	1081	358/504.ccls.	US-PGPUB; USPAT; USOCR; DERWENT	OR	ON	2008/09/22 09:04
S90	538	358/515.ccls.	US-PGPUB; USPAT; USOCR; DERWENT	OR	ON	2008/09/22 09:04
S91	326	358/519.ccls.	US-PGPUB; USPAT; USOCR; DERWENT	OR	ON	2008/09/22 09:04
S92	1984	color near2 misregistration	US-PGPUB; USPAT; USOCR; DERWENT	OR	ON	2008/09/22 09:04
S93	55	(S84 S85 S86 S87 S88 S89 S90 S91) and S92 and (CIELAB (color adj2 space))	US-PGPUB; USPAT; USOCR; DERWENT	OR	ON	2008/09/22 09:04
S94	3752	(358/515-520).ccls.	US-PGPUB; USPAT; USOCR; DERWENT	OR	ON	2008/10/07 13:45
S95	48	S94 and (color adj misregistration)	US-PGPUB; USPAT; USOCR; DERWENT	OR	ON	2008/10/07 13:46
S96	2	"7193640".pn.	US-PGPUB; USPAT; USOCR; DERWENT	OR	ON	2008/10/07 16:37

S97	7	(US-20030197877-$). did. or (US-6295374-$ or US-6198549-$ or US-6529616-$ or US-6654145-$ or US-6556313-$ or US-7256910-$).did.	US-PGPUB; USPAT	OR	OFF	2008/10/07 16:38
S98	1	"6739688".pn.	USPAT	OR	OFF	2008/10/07 16:39
S99	2	"5668931".pn.	US-PGPUB; USPAT; USOCR; DERWENT	OR	ON	2008/10/08 08:23
S100	27	("5285297" | "5317425" | "5668931" | "5721811" | "5812744" | "6009192" | "6031628" | "6262747").PN. OR ("6345117").URPN.	US-PGPUB; USPAT; USOCR	OR	OFF	2008/10/08 09:07

10/ 8/ 2008 1:08:39 PM
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Sheet 1 of 1

Form PTO-1449 (REV. 1/06) US Dept. of Commerce PATENT & TRADEMARK OFFICE INFORMATION DISCLOSURE STATEMENT (Use several sheets if necessary)	ATTY DOCKET NO. 117435	APPLICATION NO. 10/758,099
	APPLICANT(S) Paul M. BUTTERFIELD et al.	
	FILING DATE January 16, 2004	GROUP 2625

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Examiner Initials	Cite No.	Document Number	Date	Name
/R.Z./	1	US 2002-0135629 A1	11/26/2002	Sarmast et al.

FOREIGN PATENT DOCUMENTS

Examiner Initials	Cite No.	Document Number	Date	Country	With English Abstract	With English Translation
/R.Z./	2	JP-A--8160704	06/21/1996	JAPAN	X	

OTHER DOCUMENTS

Examiner Initials	Cite No.	(Including Author, Title, Date, Pertinent Pages, etc.)

EXAMINER /Richard Zhu/	DATE CONSIDERED 10/08/2008

Examiner: Initial if citation considered, whether or not citation is in conformance with M.P.E.P. 609; draw line through citation if not in conformance and not considered. Include copy of this form with next communication to applicant.

Date: June 19, 2008

ALL REFERENCES CONSIDERED EXCEPT WHERE LINED THROUGH. /R.Z

US006345117B2

(12) **United States Patent**
Klassen

(10) **Patent No.: US 6,345,117 B2**
(45) **Date of Patent: Feb. 5, 2002**

(54) **METHOD FOR AUTOMATIC TRAP SELECTION FOR CORRECTING FOR SEPARATION MISREGISTRATION IN COLOR PRINTING**

(75) Inventor: **R. Victor Klassen**, Webster, NY (US)

(73) Assignee: **Xerox Corporation**, Stamford, CT (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **09/867,346**

(22) Filed: **May 29, 2001**

Related U.S. Application Data

(62) Division of application No. 09/176,970, filed on Oct. 22, 1998.

(51) **Int. Cl.**[7] **G06K 9/00**
(52) **U.S. Cl.** **382/167**; 358/518
(58) **Field of Search** 382/167, 162, 382/266; 358/529, 1.9, 518, 523, 504, 1.4; 250/579, 550, 559.01, 559.07, 548; 345/620, 619, 418

(56) **References Cited**

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EP	0 840 500 A2	5/1998

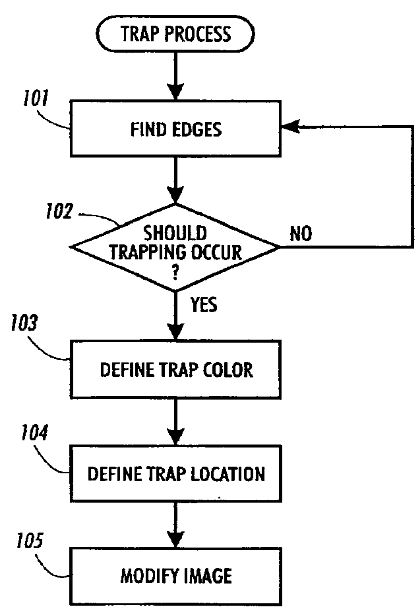
* cited by examiner

Primary Examiner—Leo Boudreau
Assistant Examiner—Ali Bayat
(74) *Attorney, Agent, or Firm*—Mark Costello; Philip E. Blair

(57) **ABSTRACT**

A color printing systems which deposits colors on a separation by separation basis is calibrated to determine a printed color responsive to a requested color, based on a mapping of device independent colors to printer output colors. The system provides trapping to correct misregistration between printer output colors due to imperfect placement of said separation color. Such a system includes calibration data stored in a device memory mapping a set of device independent colors to printer output colors; a trapping processor, using calibration data to determine device independent colors for printer colors. Also included is a trapping calculation processor, converting device independent colors to a color space in which equivalent color differences in human color perception are approximately equivalent values, determining whether to trap, a trap color, and a trapping location for the trapping color. An image modification processor is also provided to alter the image accordance with any determinations of said trapping calculation processor

6 Claims, 7 Drawing Sheets



Attachment D

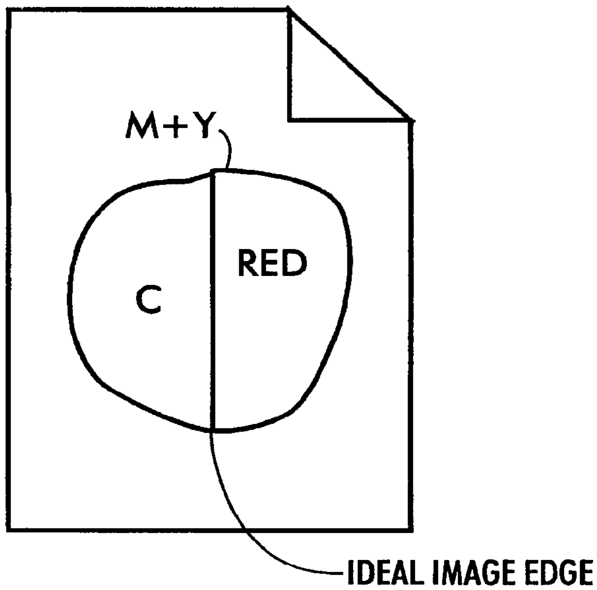
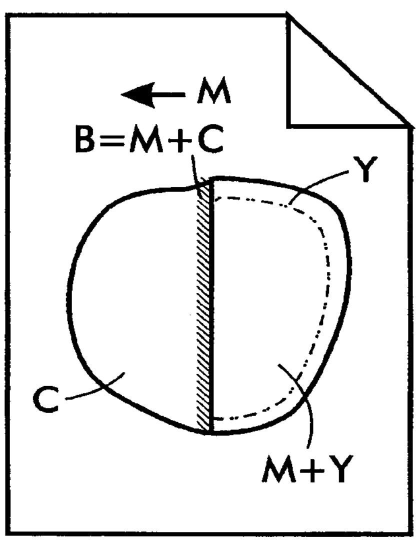


FIG. 1A



NON IDEAL IMAGE
WITH MISREGISTRATION

FIG. 1B

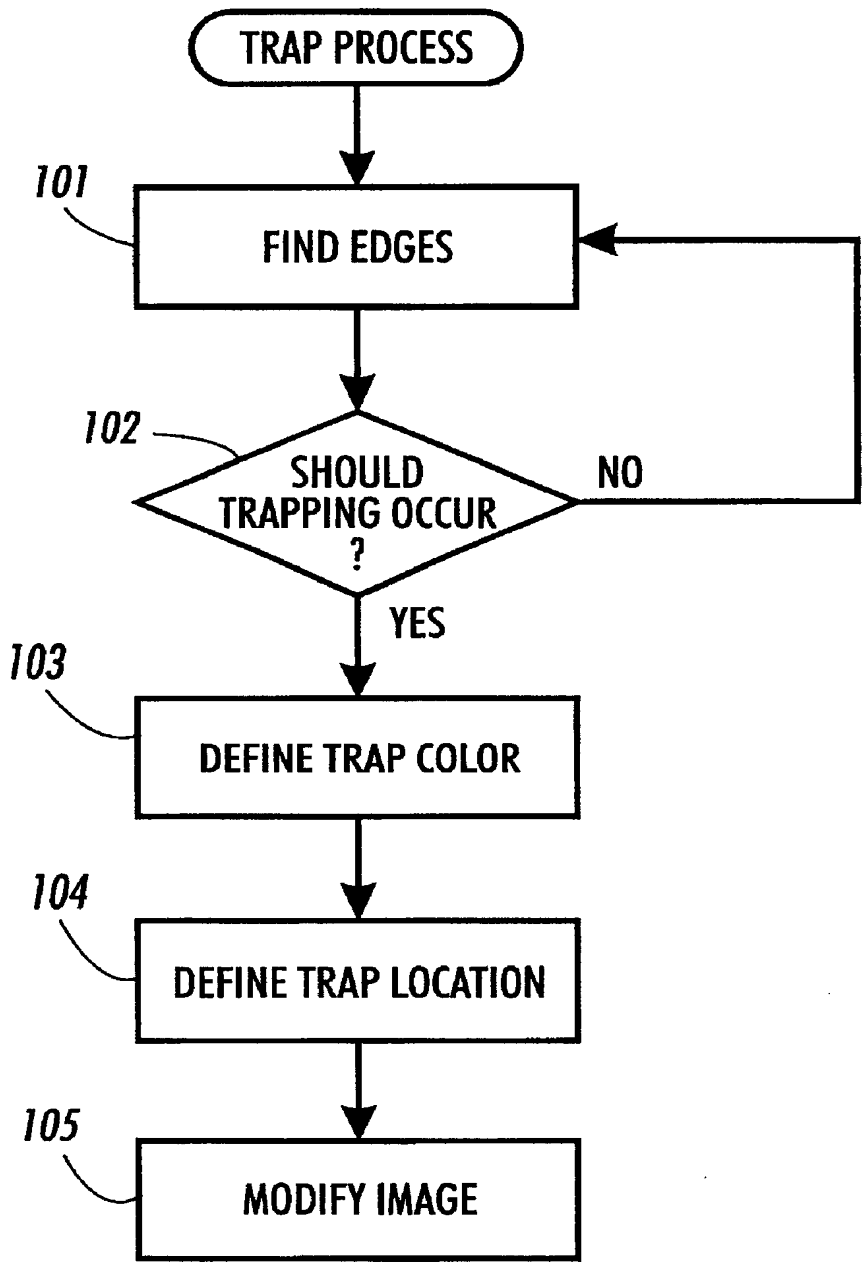

TRAP PROCESS
101
FIND EDGES
102
SHOULD TRAPPING OCCUR ?
NO
YES
103
DEFINE TRAP COLOR
104
DEFINE TRAP LOCATION
105
MODIFY IMAGE

FIG. 2

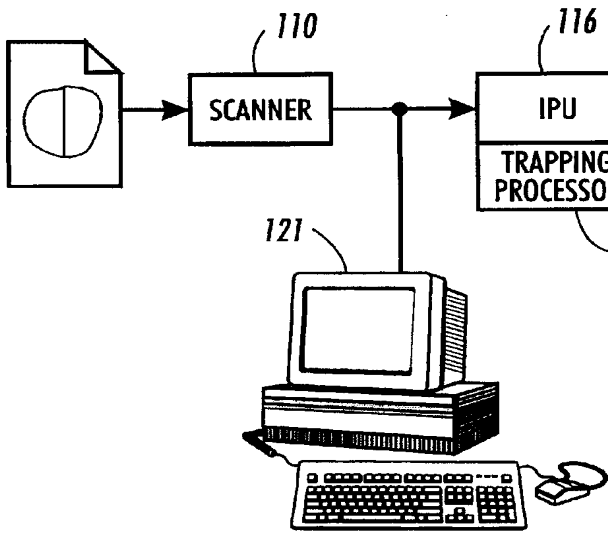

110
116
120
SCANNER
IPU
PRINTER
TRAPPING PROCESSOR
121
18

FIG. 3

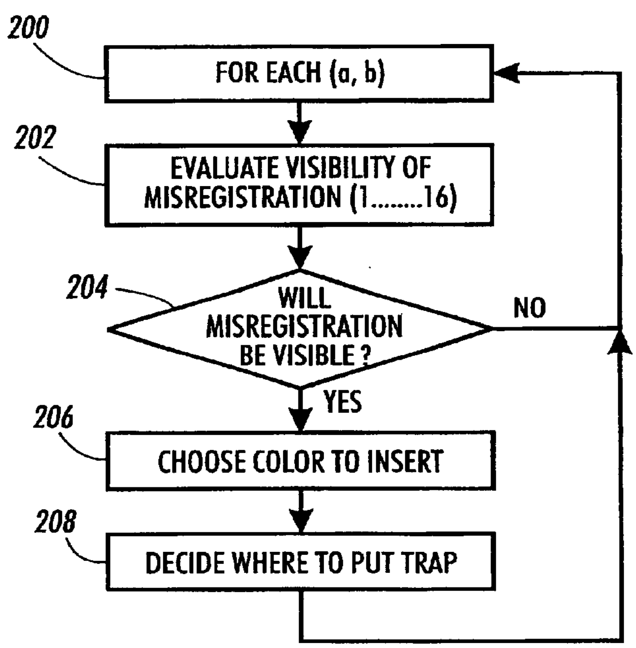

200
FOR EACH (a, b)
202
EVALUATE VISIBILITY OF MISREGISTRATION (1.........16)
204
WILL MISREGISTRATION BE VISIBLE ?
NO
YES
206
CHOOSE COLOR TO INSERT
208
DECIDE WHERE TO PUT TRAP

FIG. 4

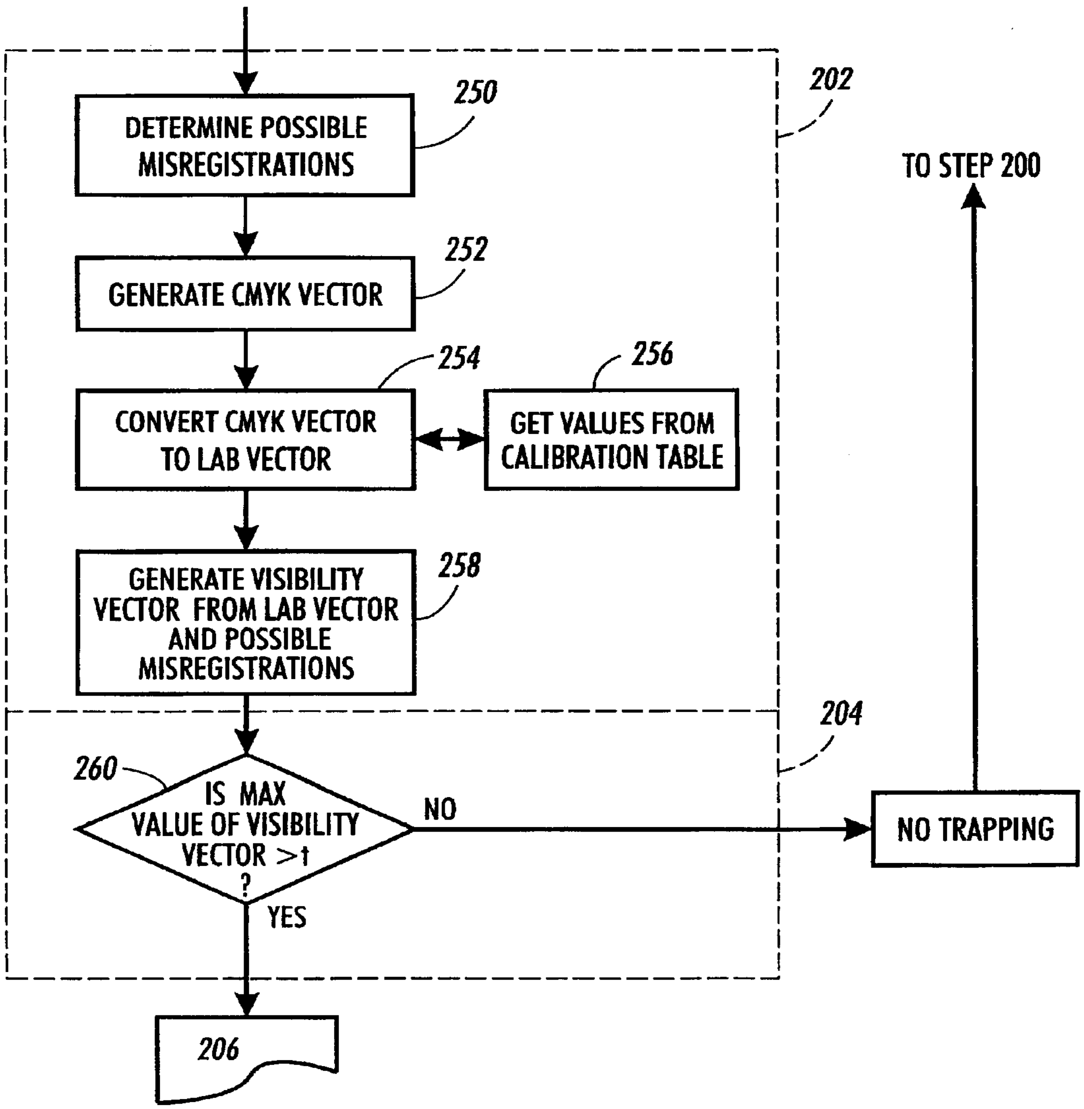
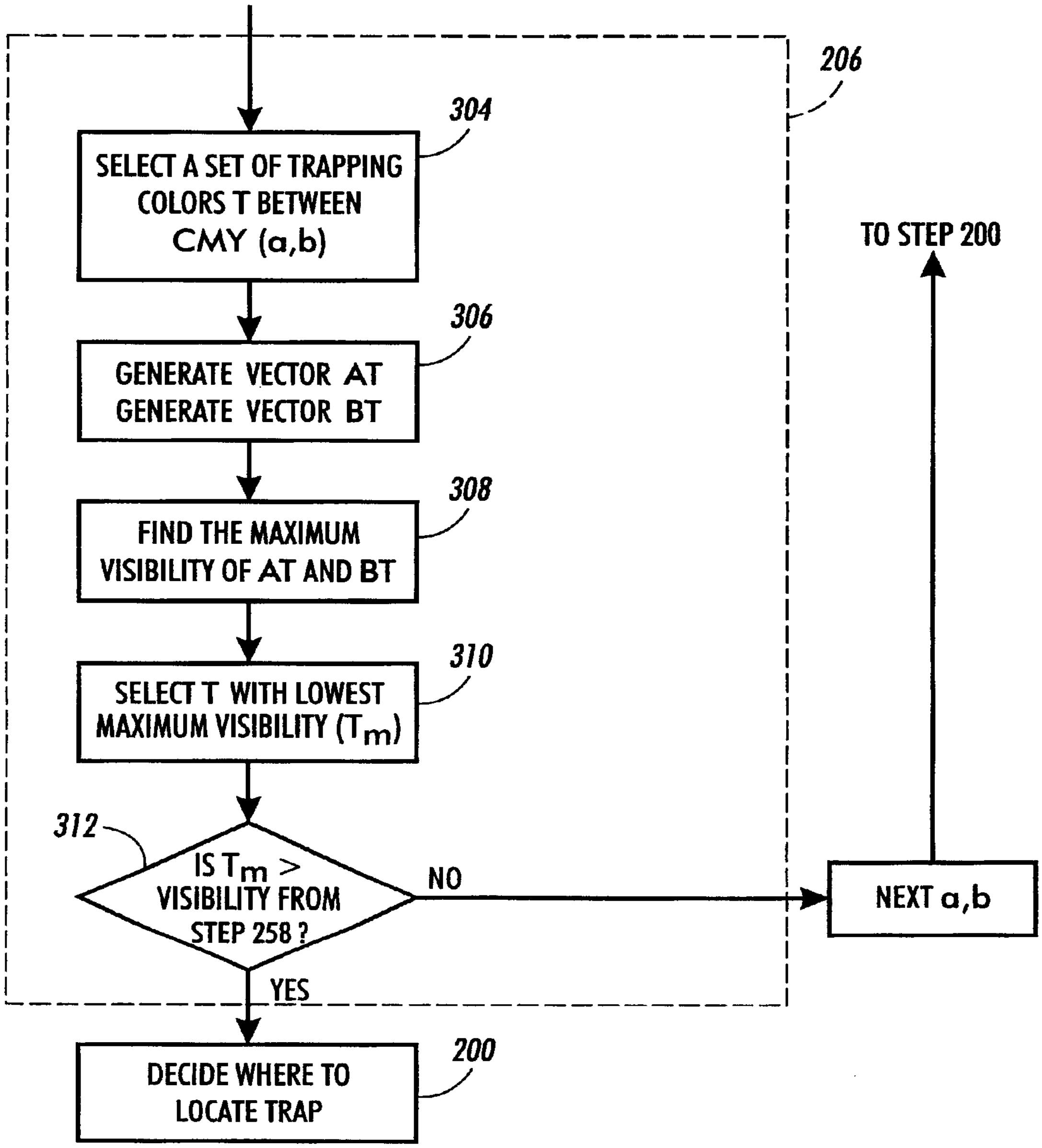

202
250
DETERMINE POSSIBLE MISREGISTRATIONS
252
GENERATE CMYK VECTOR
254
256
CONVERT CMYK VECTOR TO LAB VECTOR
GET VALUES FROM CALIBRATION TABLE
258
GENERATE VISIBILITY VECTOR FROM LAB VECTOR AND POSSIBLE MISREGISTRATIONS
204
260
IS MAX VALUE OF VISIBILITY VECTOR >t ?
NO
YES
NO TRAPPING
TO STEP 200
206

FIG. 5



206
304
SELECT A SET OF TRAPPING COLORS T BETWEEN CMY (a,b)
306
GENERATE VECTOR AT
GENERATE VECTOR BT
308
FIND THE MAXIMUM VISIBILITY OF AT AND BT
310
SELECT T WITH LOWEST MAXIMUM VISIBILITY (T_m)
312
IS T_m > VISIBILITY FROM STEP 258 ?
NO
NEXT a,b
TO STEP 200
YES
200
DECIDE WHERE TO LOCATE TRAP

FIG. 6

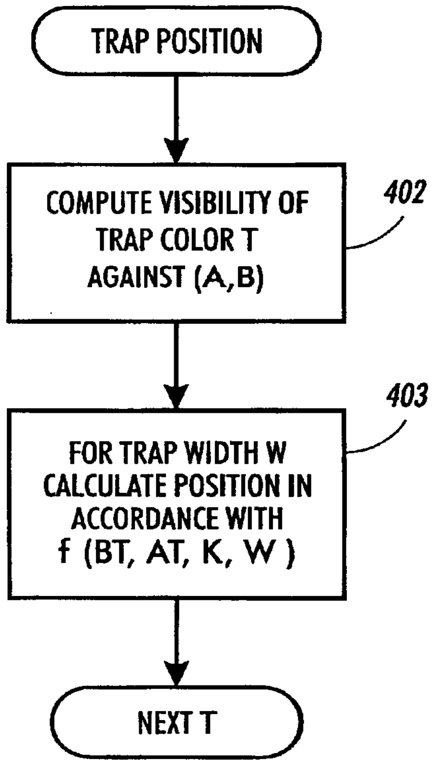

TRAP POSITION
COMPUTE VISIBILITY OF TRAP COLOR T AGAINST (A,B)
402
FOR TRAP WIDTH W CALCULATE POSITION IN ACCORDANCE WITH f (BT, AT, K, W)
403
NEXT T

FIG. 7

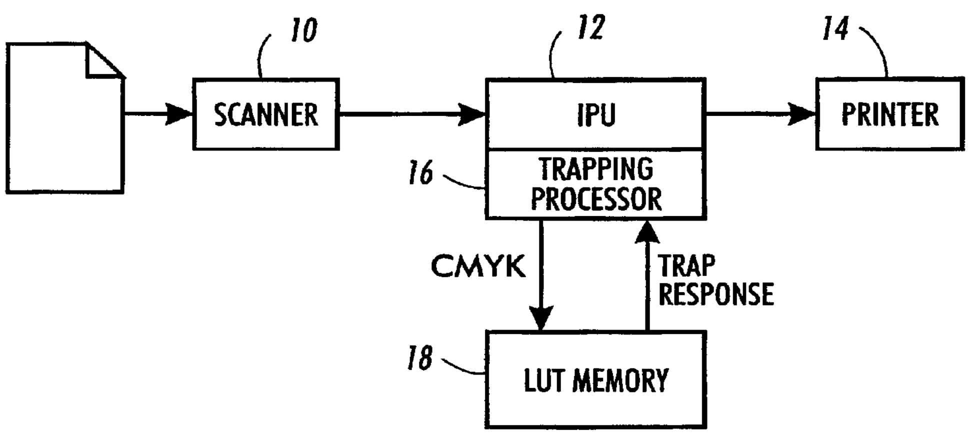

10
SCANNER
12
IPU
TRAPPING PROCESSOR
16
14
PRINTER
CMYK
TRAP RESPONSE
18
LUT MEMORY

FIG. 8

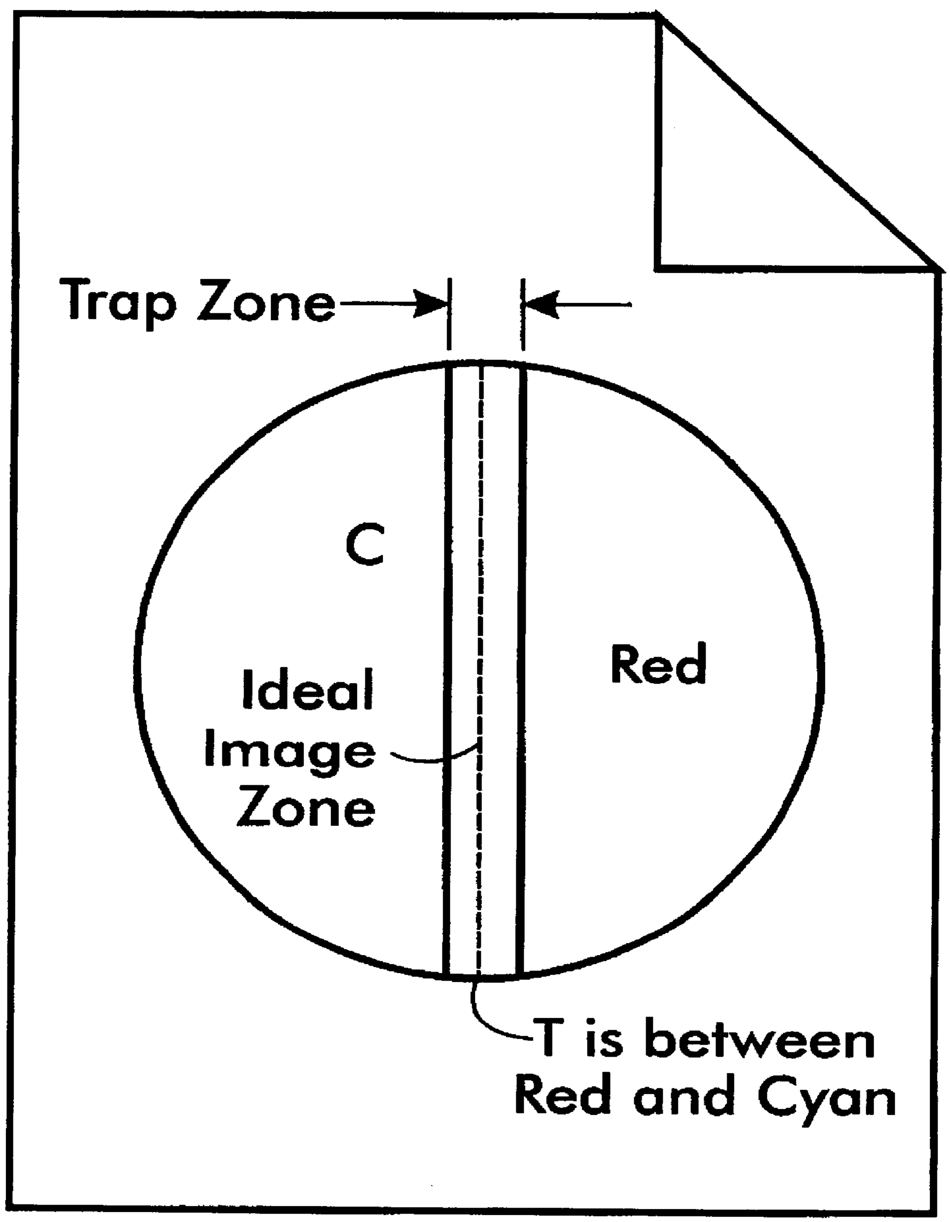


FIG. 9

METHOD FOR AUTOMATIC TRAP SELECTION FOR CORRECTING FOR SEPARATION MISREGISTRATION IN COLOR PRINTING

This application is a divisional of application(s) Ser. No(s). 09/176,970, filed Oct. 22, 1998.

This invention relates to electronic processing of graphic images to produce multi-color prints using multiple separations. Typically, four process color inks, cyan, magenta, yellow and black are used, to print multiple separations, which tend to have minor misregistration problems. Trapping is a process for adjusting images to correct for misregistration. The present invention is directed to a process for controlling trapping, based on the appearance of any misregistration artifacts against the remainder of the image.

CROSS REFERENCE

Cross reference is made to the following applications filed concurrently herewith: U.S. application Ser. No. D/98584), entitled "Method for Automatic Trap Selection for Correcting for Separation Misregistration in Color Printing" by R. Victor Klassen, and U.S. application Ser. No. D/98585), entitled "Method for Automatic Trap Selection with a Lookup Table for Correcting for Separation Misregistration in Color Printing", by R. Victor Klassen.

BACKGROUND OF THE INVENTION

The layout of a page or graphic image depends upon combining "structured graphics" according to a pre-established graphic design. The structure graphics are contiguous regions of color, usually represented in a plurality of separation images, in turn representing a succession of graphic objects imaged on the printing medium (e.g. the "paper"). The objects so imaged are shapes which can be isolated from each other, can abut one another at one or more points, can partially overlap one another, or can completely overlap one another. The resulting printed page or graphic image is therefore made up of a patchwork of shapes representing the graphic objects, some of which are "clipped" (or hidden) by objects imaged later in the succession.

The result of abutting or overlapping shapes is a boundary between adjacent regions of color which, under ideal printing conditions should have zero width. That is, the one color should stop exactly where the other begins, with no new colors introduced along the boundary by the printing process itself. The "colors" which fill the shapes can be solid colors, tints, degrades, contone images, or "no fill" (i.e., the paper with no ink applied). In general, the "colors" represented in these adjacent regions are printed using more than one colorant. In practice therefore, the realization of a zero width boundary between regions of different color is impossible as a result of small but visible misregistration problems from one printed separation to another. The error is manifested as a "light leak" or as a visible boundary region of an undesired color.

As an example, FIG. 1A shows an ideal boundary between a red region on the right and a cyan region on the left, while FIG. 1B shows a non-ideal boundary, resulting from a slight misregistration of the magenta separation to the left on the page. Between the red and cyan regions is formed a blue line, from the unintended combination of cyan and magenta. On the right-hand side of the red region will be formed a yellow line, again resulting from a slight misregistration of the magenta separation to the left on the page.

The problem of misregistration is a mechanical problem almost always existing in printing systems. The problem arises because color separations are not laid exactly where intended, due to inherent imperfections in any separation registration process. It is somewhat correctable by mechanical registration methods; however it is rarely completely correctable. In expensive, high end printing processes, customers have high expectations that misregistration artifacts will not be visible. In inexpensive, low end printers, mechanical registration techniques are so expensive as to make correction or trapping essential.

As will become apparent, different printing technologies have distinct misregistration artifacts. Offset printing tends to have uniform misregistration in all directions. However, xerographic printing tends to have more misregistration in a single direction.

Methods for correcting for this misregistration are known. The general approach is to expand one of the abutting regions' separations to fill the gap or misregistration border region with a color determined to minimize the visual effect when printed. Borders or edges expanded from a region of one color to another in this manner are said to be "spread". A border which has been expanded is referred to as a "trap", and the zone within which color is added is called the "trap zone".

Commonly used methods for automatic trapping of digital images fall into the categories of vector-based and raster-based methods. Vector-based methods rely on images that have been converted from a page-description language form, describing objects as characters, polygonal shapes, etc. into an internal data structure containing not only object information, but also a list of all the edges between regions of different color. Raster-based methods rely on images that have been first scanned or converted from page-description based form and are stored internally as a sequence of (high resolution) scan lines each containing individual scan elements or pixels. These methods process each raster line in sequence and compare one or more adjacent pixels to determine color boundaries. After some initial processing to find edges, both vector-based and raster-based methods apply rules for determining whether or not to create a trap at such boundaries, and finally apply a second set of rules to determine the nature of the trap is one is to be created.

Thus, it can be seen at FIG. 2 that most trapping processes take the following format which shall be referenced throughout this discussion.

A. Find edges in the image, no matter how described (step **101**);

B. For each pair of colors on each side of the found edge, determine:

1) Whether trapping should be used (step **102**)

2) If so, what color should be used (step **103**), and

3) Where should that color be located or placed (step **104**)

C. Modify the image accordingly (Step **105**).

The present invention focuses on several elements of Step B. Edge detection and image manipulation to perform trapping may be done in any of several standard processes.

For example, the method of Taniguchi, described in U.S. Pat. No. 4,931,861, uses two rasterized images representing abutting or overlapping objects within an image field to define a third binary image representing the map of the pixels which make up the borders between the first and second images. These three images are superimposed, pixel by pixel, to create a fourth and final binary image.

The method of Darby et al., described in U.S. Pat. No. 4,725,966, again defined on a pixel basis, uses a mask which

is moved, one resolution element at a time, to evaluate the presence or absence of (pixel) colors upon which a positive or negative spread decision is based.

The method of Yosefi, described in U.S. Pat. No. 5,113,249, uses a set of automated rules as the basis for deciding, for each pair of abutting or overlapping shapes, whether or not to create a trap (an overlap region referred to as a "frame"), and, if so, the nature of the trap to create. The embodiment described by Yosefi makes use of scanned data, and processes each line of pixels in order, comparing for each pixel three pixels from the previous scan line and two pixels from the same line to determine if a color change has occurred. The decisions regarding whether or not to create a trap, and the nature of such a trap if created are imbedded within the processing sequence, making use of criteria established prior to the onset of processing. Yosefi described rules to follow after finding an edge and knowing the two colors. There are 24 rules based on whether the colors are tints, special colors (like gold leaf), black, yellow, "window" (meaning scanned image) and various combinations.

A commercially available product, "TrapWise", from Aldus Corporation, Seattle, Wash., also makes use of a raster approach to trapping. In this product, the processing time is proportional to the number of resolution elements, thereby increasing quadratically with resolution, and leading to greater computation times for high device resolution, e.g., 3600 dots per inch (d.p.i.). Furthermore, traps are created with this package using pre-set rules, and are not editable by a user without the requirement for repeating the computation.

U.S. Pat. No. 4,583,116 to Hennig et al. describes a trapping process that evaluates the darkness on both sides of an edge in order to determine which object determines the contour. The object determining the contour is left unchanged. The other object is spread under it. The fill is constant, and matches the value of the separation being spread. The "darkest" separation is used to determine the contour and kept constant, while the lighter separations are all spread.

U.S. Pat. No. 4,700,399 describes a method that finds edges and uses a different UCR along the edges from elsewhere to allow rich black without getting color bleeding along the edges of black objects. The method requires keeping colors away from edges of black text.

U.S. Pat. No. 4,931,861 to Taniguchi describes using binary operators to shrink or spread a shape where another shape is overlapped in another separation (thresholding is used to get these shapes). Also described is spreading where two shapes are adjacent, and do not overlap.

U.S. Pat. No. 5,131,058 to Ting et al. converts a raster to an edge-based "outline" representation. Then the outlines are spread and the resulting image is re-rasterized. Spreading is done separation-wise with a process indicating whether there is a color difference that warrants spreading/choking.

U.S. Pat. No. 5,295,236 Bjorge, et al. is believed by the applicant to represent the Adobe or Aldus TrapWise product described above. This patent describes ways of deriving the information about edges required to trap, trapping with some simple rules, and converting the traps to vectors which are converted back to PDL form.

U.S. Pat. No. 5,204,918 to Hirosawa assumes vector data as input, describing the contours, i.e., no edge detection is performed. Image parts are selected in order of increasing priority. For parts of a contour of an image part where there is a lower priority image part adjacent, two supplemental contours are generated. These are offsets at a specified distance from the original contour. A new color is computed for the entire offset region (both sides of the original, not just where there is another object). The maximum density of the two sides is used in the correction region. Minimum density might be used instead. The edge following required is either done in a frame buffer, or directly on vector data.

U.S. Pat. No. 5,402,530 to Boenke et al. uses a PDL input, and builds a data-structure using a modified Weiler algorithm to represent the contours. It is object-based, in that it considers four classes of object: interior fills, strokes on the borders of regions, text on top of regions, and text on its own.

U.S. Pat. No. 5,386,223 to Saitoh et al. addresses two-color printing, extending one color into another where they abut. It suggests that it is desirable to extend the lighter color.

U.S. Pat. No. 5,542,052 to Deutsch, et al. claims a set of geometric rules. First, a relative darkness to each color is assigned, with key being the darkest color, cyan being a middle darkness color, and yellow being the lightest color. Then, the lighter color is spread under the darker color. A trap vector is drawn in a color which is a function of the two colors abutting each side of the edge.

U.S. Pat. No. 5,313,570 to Dermer, et al. takes either raster or PDL input, and creates an intermediate, vector-based form. The manipulations themselves are based on a plane sweep algorithm generating a display list and then from that display list generating a new representation called a scan beam table. The active edge table has a polygon stack for each edge. From these representations, a boundary map is generated.

U.S. Pat. No. 5,668,931 to Dermer describes trapping rules. The overall concept is to have a set of evaluation methods, and for each candidate trap, let each of the evaluation methods decide whether it is an optimum trap. Each method ranks all of the candidate traps, and then the traps are scored, using the weighted sum of the rankings. In this way some evaluation methods are more influential than others. Candidate traps appear to consist of the typical spreads and chokes, although the disclosure suggests that reduced amounts are also possible. The evaluation methods are as follows: 1) For each possible misregistration, determine the minimum distance in CIELUV from the two bounding colors, and then use the maximum of those minima as a score; 2) Determine the CIELUV distance from the trap color to the color into which it is spread; 3) For each misregistration, determine the difference in L* values from each of the bounding colors, with the score set as the maximum value of the set—i.e., favoring relatively darker misregistration colors; 4) For each misregistration color, determining the absolute difference in L* value from each bounding color, so that the score is based only on lightness differences; 5) Determine the L* value of each misregistration color, with the score indicating dark misregistration colors; 6) Determine the L* of the bounding colors and assign a score equal to the absolute difference in L* when a dark color is spread into a light, or zero when a light color is spread into a dark, penalizing the former; 7) Use the highest percentage of yellow in a misregistration color. The weights are determined empirically, and can be adjusted over time, or as a particular application demands. They are initially determined by a least squares process based on expert evaluation of a number of calibration traps.

U.S. Pat. No. 5,613,046 to Dermer describes a user interface allowing the display of an image, and selection of any color, pair, object, edge or color and modification of the trapping behavior in terms of inward/outward, or what color, how automatic or manual to be, etc. It also allows display of

the effect of any of the 16 possible misregistrations on the selected color pair, object, edge or color, with or without the current trapping applied, and to iterate through the possible modifications, applying several possible traps to see which is best.

U.S. Pat. No. 5,440,652 to Ting describes a process to find an edge and track it, building a secondary edge during processing. The secondary edge will be used as the other side of the trap region. The placement of the secondary edge and the color of the region between is determined by reference to a rule base.

U.S. Pat. No. 5,615,314 to Schoenzeit et al. describes a basic architecture for a RIP—printer interface. It includes buffering and queues and compression for transferring page images to the printer from the RIP. It also has control information, in particular, multiple copy and abort instructions. It also provides an optional dilation processor which "selectively dilates objects" in order to compensate for potential misregistration errors. There is no indication of how it selects. It dilates using "standard convolution techniques" such as taking the max of a 3x3 neighborhood.

U.S. Pat. No. 5,513,300 to Shibazaki describes trapping rasters against line art. They are concerned with the image and line art being at different resolutions. Line art is stored as run length data, and images as raster. The method forms a mask indicating where the image appears, and erodes or dilates the mask. The non-exempt separations of the image of line art are then copied into the eroded or dilated regions (respectively). A separation is exempt if the operator so indicates.

U.S. Pat. No. 5,386,483 to Shibazaki discusses finding a trapping region in a raster-based image. The image is segmented into regions, each of a constant color. Each such region is assigned a region number, and a lookup table is used to store the correspondence between region number, and colors, including both CMYK, and RGB. RGB is used by the operator supervising the process with a display and mouse. The data is then run-length encoded, using runs of color table indices. The algorithm is multi-pass. On the first pass, an eight-neighbor window is used to form a pair of "frame" regions along each color boundary. On subsequent passes, a four-neighbor set is used to extend the frame region. Finally, a color is assigned to each new region thus formed. To form a "frame" region, a three scanline buffer is used. The center pixel in a window is considered to be in the frame region if 1) the pixel is located in one of the original regions (i.e., not already in a frame region), and 2) at least one neighbor is in a different region. Regions/colors have priorities specified (by the user). When the neighbor with the highest priority is part of a frame, the frame number is used for the new region of the pixel. Otherwise, a new frame number is allocated and used. It appears that priorities don't change when pixels are assigned to frame regions.

U.S. Pat. No. 5,241,396 to Harrington describes a simple raster-based technique for protecting rich black text. Black separation images are eroded and then ANDed with each of CMY separations, to produce new cyan, magenta and yellow separations. The original black is then used as the black separation.

U.S. Pat. No. 4,700,399 to Yoshida finds edges and uses a different UCR along the edges from elsewhere to allow rich black without getting color bleeding along the edges of black objects. Colors are kept away from edges of black text.

U.S. Pat. No. 5,666,543 to Gartland and U.S. Pat. No. 5,542,052 describes an arrangement providing a prolog substituted to turn on trapping. The prolog instructs the RIP to build a "shape directory" and then to trap the objects in the shape directory. The shape directory appears to be a back-to-front display list. Objects are processed in the back-to-front order. If they overlap existing objects, they are trapped against them. If the existing object already has been trapped, the traps are undone before the new traps are introduced. Thus traps are introduced as objects are processed, possibly causing a region to be trapped and re-trapped as the traps are covered up. The decision of whether to trap includes text point size and changes in separation strength.

The trapping methods described in the above cited prior art references have two common features. The first is that most process images represented in raster form. This feature places a requirement for extra processing steps in images which constitute primarily structured graphics or which combine structured graphics with contone images. Such images must first be rasterized at the output resolution, and then the appropriate line-scan algorithm applied.

The second common feature of prior art methods is the necessity to make and apply trapping decisions within the processing based upon pre-established criteria. For raster based processing at high output device resolution, the potential number of pixel-to-pixel color transitions is large due to repetition of transitions corresponding to a single color region border shared by many scan lines.

Many rule-based methods exist in the prior art for automatic determination of the particular trap to be specified for a given combination of bounding colors. For example, in U.S. Pat. No. 5,113,249, a set of logical tests is used in sequence to differentiate between pre-established generic color-pair categories, with a rule applied to each color pair. Such built-in rule systems attempt to replicate the human aesthetic judgment used in manual specification of traps and each can provide results satisfactory to an "expert" user in most cases while failing to do so in other special situations. Without a means for configuring the automatic trap selection method, a user is forced to rely on manual trap specification, even for routine operations.

The specification of a trap at the boundary between two color regions does not in itself eliminate the misregistration of printing plates, but reduces the visual effect of misregistration within the trap zone through proper choice of the trap operation. In the event of plate misregistration involving a color separation for which a trap has been specified, additional "secondary" effects occur. The secondary effects should not cause the image to be worse than when untrapped.

Prior trapping methods describe using either luminance, which is a somewhat poorly defined term, or a different and more precise parameter called lightness in determining whether to trap. The methods described use luminance or lightness values directly by assessing the difference in luminance (in some cases) or lightness (in other cases) across an edge in order to decide whether to generate a trapping zone. Generally, these values are not used in more precise measures of human perception, however. As a result, the use of luminance or lightness contrast across an edge does not always provide an adequate indicator of whether a gap created by misregistration will be visible at the edge.

Yet another problem associated with trapping is where to put the trap color. Yosefi, above indicates that this is done by spreading the darker separations of the lighter color in the direction of the darker color. Much the same approach is indicated in the specifications of other patents that address the issue: make a trap region that consists of the dark separations of the light color and the remaining separations of the dark color, and put the trap region on the dark side of

the edge. Lawler, "The Complete Book of Trapping" Hayden Books, 1995, pp 21, 22, recommends spreading the lighter color into the darker color (at full strength), but when describing the determination of which color is lighter, suggests only that secondary colors are darker then the primaries they contain.

Specific models of the visibility of colored thin lines adjacent to colored backgrounds have not been noted, however there are models of the visibility of differences of color between two large colored backgrounds. A. R. Robertson, "Historical development of CIE recommended color difference equations", *Color Research and Applications*, 15, (3), June 1990 describes the origins of CIE L*a*b* and CIE L*u*v* color spaces. (CIE, refers to the Commission Internationale de l'Eclairage, an international standards committee specializing in color). These two spaces had the common goals of being simultaneously easy to compute, and perceptually uniform. Neither space is truly uniform throughout color space, but they have the merit of being readily computed. These two standard color spaces were adopted in 1976. In both of these color spaces L* is a correlate of lightness, while the other two coordinates give a way of specifying a color independent of its lightness. For example, in the L*a*b* system, larger values of a* indicate colors with more red in them while larger values of b* indicate colors with more yellow in them. Smaller values of a* indicate less red, or more green, while smaller values of b* indicate more blue (less yellow).

LAB color space, or CIELAB color space is based directly on CIE XYZ (1931) and represents an attempt to linearize the perceptibility of unit vector color differences. It is non-linear, and the conversions are reversible. Coloring information is relative to the color of the white point of the system, (X_n, Y_n, Z_n). The non-linear relationships for L*a* and b* are intended to mimic the logarithmic response of the eye.

$L^*=116((Y/Y_n)\hat{}(1/3))-16$ for $Y/Y_n>0.008856$

$L^*=903.3(Y/Y_n)$ for $Y/Y_n<=0.008856$

$a^*=500(f(X/X_n)-f(Y/Y_n))$

$b^*=200(f(Y/Y_n)-f(Z/Z_n))$

where $f(t)=t\hat{}(1/3)$ for $t>0.008856$

$f(t)=7.787*t+16/116$ for $t<=0.008856$

Again, L* scales from 0 to 100.

To calculate the difference between two colors in either CIE L*a*b* or L*u*v space, one would normally use the Euclidean distance in the color space. For example, in L*a*b*, space one would calculate the difference between two colors as $\Delta E=(\Delta L^{*2}+\Delta a^{*2}+\Delta b^{*2})^{1/2}$. Here ΔL^* is the difference between the two colors in the L* coordinate, etc.

The CIE color space specifications also include definitions of hue and chroma, so that for the L*a*b* space, they define $h_{ab}=\arctan(b^*/a^*)$ and $C_{ab}^*.=(a^{*2}+b^{*2})^{1/2}$. In this form, ΔC is the difference between the two chroma values, but $\Delta H_{ab}=(\Delta E_{ab}^{*2}-\Delta L^{*2}-\Delta C_{ab}^{*2})^{1/2}$.

Because of the lack of true uniformity in these color spaces, further refinements have followed. Of particular interest is the CIE94 color difference model (CIE Publication 116-1995: Industrial color-difference evaluation (Technical Report) CIE Central Bureau, Vienna 1995). In this formula, $\Delta E94=((\Delta L^{*2}/k_L S_L)^2+(\Delta C_{ab}^{*2}/k_C S_C)^2+(\Delta H_{ab}^{*2}/k_H S_H)^2)^{1/2}$, with specific functions weighting each of lightness, chroma and hue differences. For the reference viewing conditions, all of the k parameters are kept at 1. They are free to change with changes in the viewing geometry, etc. The "S" functions were specified as $S_L=1$; $S_C=1+0.045\ C^*_{ab}$, and $S_H=1+0.015\ C^*_{ab}$. Thus, the larger the chroma (i.e., the more colorful the colors being discriminated), the larger a change in hue or chroma people need before they can see that two colors are not the same. This color difference model provides a marked improvement over the Euclidean distance ΔE_{ab}^*, but is only applicable for large regions obeying a specific geometry.

Due to the optics of the eye, the spacing of the receptors and the wiring of neural pathways leading to the brain, we can see fine detail best when it differs from the background in lightness. If there is no lightness variation, we can see detail better if it differs in redness (or greenness). Specifically, it is very hard to see fine detail in blue-yellow variation. Zhang and Wandell "A spatial extension of CIELab for digital color image reproduction", SID 96 describes a method of finding the visual difference between two images by first converting the images into an opponent color space, and then filtering the lightness channel, the red-green channel, and the blue-yellow channel each by different filters. The lightness is blurred least, and the blue-yellow channel the most, by these filters. In their paper, the resulting images are converted to CIEL*a*b* after blurring, and then the image difference is an image consisting of, at each pixel, ΔE_{ab}^*, taken between corresponding pixels of the (filtered) two original images. Zhang and Wandell name this metric S-CIELab. An improvement over S-CIELab is to use the CIE94 color difference metric in the place of ΔE_{ab}^*, otherwise leaving S-CIELab unchanged.

Note that one can compare any two images. In particular, if one wishes to know whether a line induced by misregistration would be visible, one could compare an image with the line to one without the line. If the pixel with the largest error in the difference image has an error above some threshold, the line is visible.

The above patents and references and particularly U.S. Pat. No. 5,313,570 to Dermer, et al. and U.S. Pat. No. 5,668,931 to Dermer are hereby incorporated by reference for their teachings.

SUMMARY OF THE INVENTION

In accordance with the invention, there is provided a method of generating a misregistration visibility metric and using the misregistration visibility metric to decide whether to trap, what trap color to use, and where to place the trap. From this metric, a trapping solution can be generated that will be least visible either when there is a gap filled in, or when there is no gap, and hence an overlap created by the trap.

In accordance with one aspect of the invention, there is provided a printing system for printing images with colors formed by overlapped combinations of separately deposited separation colors, each separation color corresponding to a colorant, said printing system calibrated to determine the printed color responsive to a requested color, based on a mapping of device independent colors to printer output colors, and providing trapping to correct misregistration between printer output colors due to imperfect placement of said separation colors, including calibration data stored in a device memory mapping a set of device independent colors to printer output colors; a trapping processor, using said calibration data to determine device independent colors for said printer colors, and including: a trapping calculation processor, converting said device independent colors to a color space in which equivalent color differences in human color perception are approximately equivalent values, determining whether to trap, a trap color, and a trapping location for the trapping color; and an image modification processor, suitable for altering a received image in accordance with any determinations of said trapping calculation processor.

In accordance with another aspect of the invention, the printing system includes a calibration processor, accessing printer output colors in said device memory, for output responsive to receiving device independent colors describing an image to enable use of human color perception in a particular device dependent system.

The invention provides a trapping system based on visibility to the human eye, which is ultimately the determiner of the best trapping effect. In order to effectively operate, the system operates within a calibrated printing system which allows operation in device independent space, for application to device dependent space. Conveniently, much of the information required for the process exists in a calibrated printing system.

The described invention provides an efficiently calculated, table based trapping method, which may be easily altered based on device or user experience. The method allows ready alteration of the trapping process due to new material or process parameters.

Prior trapping methods describe using either luminance, which is a somewhat poorly defined term, or a different and more precise parameter called lightness in determining whether to trap. The methods described use luminance or lightness values directly by assessing the difference in luminance (in some cases) or lightness (in other cases) across an edge in order to decide whether to generate a trapping zone. Generally, these values are not used in more precise measures of human perception, however. As a result, the use of luminance or lightness contrast across an edge does not always provide an adequate indicator of whether a gap created by misregistration will be visible at the edge. In accordance with the present invention, since the most important criteria is how visible is the result of misregistration, in the event that it should occur, proposed is the use of an estimate of that visibility, which includes the use of lightness coupled with other color parameters, to decide whether to trap. Furthermore, rather than looking at the change of visibility across an edge, the method uses the visibility of various potential misregistrations and various potential trap colors if used, whether or not misregistration should occur.

Prior methods of trapping emphasize rules and heuristics to determine the need for trapping, trapping colors, and placement. A key element of the present invention is using estimated visibility as a criteria for making the above mentioned three determinations.

These and other aspects of the invention will become apparent from the following description used to illustrate a preferred embodiment of the invention in conjunction with the accompanying drawings in which:

FIGS. 1A and 1B illustrate the problems of misregistration at edges in color images;

FIG. 2 shows a flow chart showing the basic procedure of trapping;

FIG. 3 shows a printing system, in which one example of the present invention might be implemented;

FIG. 4 shows a flow chart showing a procedure for trapping using visibility as a criteria for controlling trapping processes;

FIG. 5 shows a flow chart illustrating a sub-procedure of determining visibility;

FIG. 6 shows a flow chart illustrating a sub-procedure of selecting trapping colors;

FIG. 7 shows a flow chart illustrating the basic sub-procedure of selecting the position for the trap;

FIG. 8 shows the problem of placement of the trap color; and

FIG. 9 shows an embodiment of the invention utilizing a lookup table storing trapping information.

Referring now to the drawings where the showings are for the purpose of describing an embodiment of the invention and not for limiting same, a basic image processing system is shown in FIG. 1, where gray image data may be characterized as image signals, each pixel of which is defined at a single level or optical density in set of 'c' optical density levels.

As used herein, a "pixel" refers to an image signal associated with a particular position in an image, having a density between a minimum and a maximum. Accordingly, intensity and position define pixels. In the particular color system to be discussed, color documents are represented by multiple sets of image signals, each set (or separation) represented by an independent channel, which is usually processed independently. A "color image" as used herein is therefore a document including at least two separations, or sometimes more than 4 separations (sometimes referred to as "hifi color". Each separation provides a set of image signals or separation pixels, which will drive a printer to produce one color separation of the image. In the case of multicolor printers, the separations, superposed together, form the color image. In this context, we will describe pixels as discrete image signals, which represent optical density of the document image in a given small area thereof. The term "separation pixel" will be used to refer to such an image signal in each separation, as distinguished from "color pixel", which is the sum of the color densities of corresponding pixels in each separation. "Gray", as used herein does not refer to a color unless specifically identified as such. Rather, the term refers to image signals, which vary between maximum and minimum, irrespective of the color of the separation in which the signals are used. Documents may include plural "objects". An object is a discrete image element, which may be processed distinctly from the remainder of the document. Objects commonly fall into types, including, for example, photographs, graphics, text, halftones, etc. High quality systems process objects of different types distinctly, for optimum rendition of each type.

Refer now to FIG. 3, which shows a general system requirement representing the goal of the invention. An electronic representation of a document (hereinafter, an image) from image input terminal such as scanner 10 is derived in a format related to the physical characteristics of the device, and commonly with pixels defined at m bits per pixel. Common color scanners have a pixel depth of 8 bits/separation pixel, at resolutions acceptable for many purposes. Alternatively, the image could be generated with appropriate image generation software at a computer or workstation 121. Since this is a color document, the image is defined with two or more separation bitmaps, usually with identical resolution and pixel depth. The electronic image signals are directed through an image processing unit (IPU) 16 to be processed so that an image suitable for reproduction on image output terminal or printer 20 is obtained. Of course, the IPU 16 could represent a software program in a general purpose digital computer. For the purposes of this discussion, image processing unit 16 commonly includes a trapping processor 18 which corrects for traps formed at color edges.

FIGS. 1A and 1B illustrate the problem of trapping. In an ideal image, changes in colors occur exactly at a preplanned location, as shown in FIG. 1A. However, misregistration, common in real world devices using plural separations independently printed, often results in a visible image arti-

fact or defect, as shown in FIG. 1B. Such defects can be compensated with trapping.

Trapping usually takes place in accordance with the showing of FIG. 2, in which, a) for any pair of colors (which may or may not correspond to an edge), a decision must be made b1) whether to trap; if so, b2) which color to use for the "trap color", (the color to interpose between the colors of the pair) and b3) where to place the chosen trap color. In accordance with the invention, the decision to trap is based on the visibility of the worst artifact that could happen. Thus, the decision to trap is based on the visibility of the worst of all possible misregistration errors between the input colors. Subsequently, trap colors are chosen based on the visibility of the added trap color against each of the original colors, and based on the visibility of misregistration-induced colors against each of the original colors.

As has been discussed, trapping is a phenomenon of non-ideal printing devices. Trapping characteristics vary from printing technology to printing technology. In accordance with another aspect of the invention, information about the printing technology, or even regarding a particular printer, may be used to optimize the trapping process to be described.

Initially, the process of the invention will be described with reference to the flow chart of FIG. 3. Such a flow chart is readily convertible to a program running on a general purpose digital computer, or a special purpose processor built to provide such operation.

Given a pair of colors (a, b) to be trapped (step **100**), the trapping process takes the following form:

1. Check for visibility of potential misregistrations (step **202**);
2. Determine whether any misregistration will be visible (step **204**);
3. If a misregistration is likely to be visible, choose the color to insert (step **206**); and
4. Decide where to put the trap (step **208**).

In considering step **202**, and input colors (a,b), a list (Misregister (a,b)) is produced of all the unique colors that would appear between colors a and b, if a and b are misregistered in all possible ways. The assumption is that the worst case is that one or more of the separations is moved all the way from its nominal location to the edge of a specification, determined epmirically by the printing process (See, FIGS. 1A and 1B). An alternative assumption would allow some separations to move only part way, thereby inducing more colors along the edge. We consider the case of one color along the edge.

A function Misregister(a,b) runs through all possible substitutions of a separation in a with a separation in b. There are, at most, 14 such substitutions. (Each of four separations is either substituted or not—but two cases, "all" or "none" substituted, do not require processing). Table 1 shows the colors that could appear on the left of an edge between the CMYK color (1,1,1,1) on the right with (0,0, 0,0) on its left. Two of those colors are the original colors, leaving 14 possible new colors.

TABLE 1

#	Cyan	Magenta	Yellow	Black	Colors shifted left
1	0	0	0	0	none
2	0	0	0	1	black
3	0	0	1	0	yellow

TABLE 1-continued

#	Cyan	Magenta	Yellow	Black	Colors shifted left
4	0	0	1	1	yellow, black
5	0	1	0	0	magenta
6	0	1	0	1	magenta, black
7	0	1	1	0	magenta, yellow
8	0	1	1	1	magenta, yellow, black
9	1	0	0	0	cyan
10	1	0	0	1	cyan, black
11	1	0	1	0	cyan, yellow
12	1	0	1	1	cyan, yellow, black
13	1	1	0	0	cyan, magenta
14	1	1	0	1	cyan, magenta, black
15	1	1	1	0	cyan, magenta, yellow
16	1	1	1	1	all

These 14 colors are sorted according to an arbitrary sort order, considering two separations equal if they differ by less than a small tolerance. Then duplicates are removed. Finally, two more cases (if they occur) are removed: substitutions where one of the original colors results, which happens at least once whenever one or more separations is in common. This gives a (usually) smaller list, which is stored in a structure containing a 14 element array and a single integer giving the number of colors in the list. For purposes of discussion, we call the type of this structure CMYKvector (step **252**). Colors are given as c, m, y, k tuples, encapsulated as a signal or set of signals of type CMYKcolor.

The determined colors are then converted to LAB space (step **254**). LABvector, is a signal or set of signals representing the possible misregistration colors in LAB space. LABvector is constructed from CMYKvector using device dependent color conversion, a process which entails a prior generation of samples of CMYKcolors, organized into a table, and mapped to LAB space, either directly or through an intermediate space. Before the first LABcolor is constructed, the necessary lookup tables are initialized as appropriate to the particular printer for which the colors are being converted. Since such a process is dependent on discrete sample points in CMYK and LAB space, intermediate, interpolated values can be derived by tetrahedral interpolation (see, for example, U.S. Pat. No. 5,471,324 to Rolleston and U.S. Pat. No. 4,725,413 to Sakamoto). Any color calibration system begins by measuring the LAB colors generated when a variety of CMYK colors are printed. These colors are interpolated to get the LAB color for the given CMYK color. Because the conversion is specific to the printer or type of printer, the visibility computed depends on the printer as well, as it should, since a particular amount of (C,M,Y,K) printed on one printer will not necessarily produce the same visual impression as the same amounts of colorants printed on a different printer. Many printing systems are calibrated, so that for a given device independent color, a predetermined device dependent color is produced, derived from a prior calibration process in which the device operation was measured to determine its response. If the trapping process is to be used on an uncalibrated printing system, the conversion of device independent and device dependent values must still be determined.

The reason for placing the colors into CIELAB space, or a similar space CIELUV, is that these spaces have a strong connection to visually perceptible color differences, which allow them to be used to determine, irrespective of the misregistration color, whether that color is likely to be visually perceptible. At the heart of this requirement is the observation that misregistered separations can result in color

differences from the desired image, with the differences not plainly visible. Changes should only be made where the color differences due to misregistration are visible. Differences observed in CIELAB or CIELUV have a relationship to visibility in human color perception. This visibility is usable as a metric for how apparent a trap or trap modification can be.

Accordingly, at step **204**, where we determine whether misregistration is visible, the color space aids in our calculation, because perceptible differences are relatively linear. With reference to FIG. **5**, initially, a Visibilityvector (a,b) is constructed (step **258**), and tested to see whether the max value of the vector is greater than a threshold (step **260**). The color difference formula is designed to give a value 1 at the limit of visibility, hence one good value of the threshold is 1.

One color difference formula that works well is derived from the CIE94 difference formula, and based on experimental data of the visibility of thin lines against a uniform colored background, viz.

$$DE94=((\Delta L/1.34)^2+(\Delta C_{ab}/S_C)^2+(\Delta H_{ab}/S_H)^2)^{1/2}$$

with

$$S_C=(a_C C^*+k_C)(1+b_C(A0_c\cos(H^*-f0_C)+A1_c\cos(2H^*-f1_c))),$$

and

$$S_H=(a_H C^*+k_H)(1+b_H(A0_H\cos(H^*-f0_H)+A1_H\cos(2H^*-f1_H)))$$

	C	H
a	.085	.008
k	6.3	6.5
b	.08	.004
A0	4	7.3
A1	3.3	5.3
f0	958	848
f1	2408	108

A different metric, which appears to work nearly as well, is to compute images with and without the defect, and then use these images as input to S-CIELab with the CIE94 difference metric replacing the ΔE_{ab} normally used to compute the final difference. The largest pixelwise difference in the entire difference image then gives the difference for this formulation.

In order to construct a Visibilityvector as in FIG. **5**, each of the input colors a and b is converted to an L*a*b* equivalent. In order to construct an LAB color, given a CMYK color, we need to employ tetrahedral interpolation, or some other commonly known method of converting from device coordinates to device dependent color space. The process than loops through each of the elements (the possible misregistrations) of the LABvector, and computes the difference from a and from b for that element. It stores the minimum of these two differences. The minimum is the right one to store, because if c (the misregistration induced color) is less visible against a than against b, and c is between a and b, we might see c as part of a. This is certainly true if c is invisible against a but visible against b. It then appears that the edge between a and b is shifted, rather than that there is a misregistration error. As previously noted, the above values are often present in calibrated printers, and can therefore be used in trapping processing.

At step **258**, a Visibilityvector is constructed from two colors (a, b) and the list of misregistration colors, and a list of values is built which correspond to the visibilities of all the misregistration colors. If the maximum entry in the Visibilityvector is less than a threshold value t(FIGS. **4** and **5**, step **204**), the misregistration will not be visible. No action is taken at these two colors, and the next set of two colors is reviewed. However, if the maximum is greater than a threshold value t, the process continues to select a color for the trap (step **206**). If the value of t is increased, fewer color pairs will be selected for trapping, and the process of checking for misregistration will proceed faster. However, image quality will be reduced. On the other hand, decreasing the value of t will result in more color pairs selected for trapping, and the process of checking will proceed slower. Generally image quality will be enhanced.

With reference to FIGS. **4** and **6**, a step **206**, the trapping color is selected or determined. Generally, a predetermined set of trapping colors is maintained as a palette, with selection throughout the gamut of a device (see "select a set of trapping colors CMYK(t)", step **300**). User preferences can be used to generate the palette.

To choose the color to insert between a and b, every color T in the palette is compared to colors CMYK(a,b) (step **302**) to see if T is between a,b (step **304**). Color T is not "between" if any of the values of C, M and Y for T are not between those for a and b (K may be ignored). Such colors not between a,b are discarded. For each T for which C, M and Y are between a,b, a Trap_Visibilityvector AT is generated for a and T, and a Trap-Visibilityvector BT is generated for b and T. (Step **306**). From the two Trap_Visibilityvectors, maximum visibility t_m in AT and BT are determined (step **308**). This gives the visibility of T against a or b, assuming the worst misregistration happens for one or the other of a and b. Of all the candidate colors T tried in the above loop, the one with the lowest maximum visibility T_m is selected as representing the best trapping color candidate (Step **310**).

At this point in the process, a check is performed to determine if the visibility of the candidate color is worse than the initial misregistration visibility found in step **258** of FIG. **5** (step **312**). If it is, no trapping is applied. Otherwise, however, the process proceeds to step **208**, using the candidate color T whose worst visibility is the best of all the candidate colors tried. It has also been found that a good alternative to using the color with the least worst visibility, is taking the sum of the squares of the visibilities over all misregistrations and choosing the candidate with the smallest sum. In either case, the different visibilities might be weighted, given a priori knowledge of which misregistrations are more likely to occur.

Other approaches are possible, e.g. a multigrid approach in which color space is sampled very coarsely, and then the region of the best solution is sampled more finely.

Trap_Visibilityvector is a class that behaves much like Visibilityvector. From two colors and a vector of misregistration colors a vector is built which correspond to the visibilities of all the misregistration colors. In the case of Trap_Visibilityvector the first color is the original color and the second color is the candidate trap color. The vector of misregistration doubles is one longer than the vector of misregistration colors. The visibilities are measured only between the original color and the misregistration colors, and between the original color and the candidate trap color, not between the candidate trap color and the misregistration colors. The use of this value is analogous to Visibilityvector, except that the second color is not compared against the misregistration colors, and the second color is compared against the first color.

With reference again to FIG. **5**, now that the color of the trap has been selected, a decision must be made as to where to put it (step **208**, FIG. **4**). When trapping, we interpose a new color between two colors that might misregister, thereby reducing or eliminating the visibility of any misregistration that should occur. This aspect of the invention relates to the location of the interposed color (trap). Specifically, the new color is put on one side of the original edge when the trap color is not very visible against the color on that side of the edge, and on the other side when it is not very visible against the color on the other side. When it is equally visible, the trap color is centered. By making the edge position a function of the difference between the two visibilities, we make the position smoothly vary from one side to the other when gradient fills abut. If the one color is in text, the position is not varied smoothly, but rather moved all the way over to one side or the other (whichever is less visible), to maintain the edge location of the text.

Given the above, and with reference to FIGS. **7** and **8**, the optimum place to put the trap color is on which ever side makes it less visible. Specifically, if trapping between color A and color B with trap color T, compute visibility by determining the Visibilityvector AT of T against A, and Visibilityvector BT of T against B (step **402**). The vectors are initially converted to scalar values by taking a vector norm to drive bt and at. For trap width w, if A is to the left, move the center of the trap region to the left by (BT-AT) *k*w, for some value of k that depends on the particular model of visibility being used, subject to not moving it more than ±w/2 (Step **402**). Other functions relating the relative visibility of T against colors A, B may be used. Half-bitting allows the trap zone to move in increments of ½ of a pixel, so for a trap width of 2 pixels, this allows 5 positions. Thus, a smoothly varying trap position can be obtained.

The visibility can be computed using S-CIELab-94, a spatially extended color difference metric, extended to use CIE94 color differencing, or from any other model of visibility that applies to thin lines against large background constant background regions. Currently visibility is measured by:

$$Vis(A,T)=((\Delta L/S_L)^2+(\Delta C/S_C)^2+(\Delta H/S_H)2)^{1/2}$$

where

$\Delta L=L_A-L_T$, the difference between the L* values of A and T;

$\Delta C=C_A-C_T$, the difference between the C* values of A and T;

$C^*=(a^{*2}+b^{*2})$½, with a* and b* the standard CIE coordinates.

$\Delta H=((\Delta a)^2+(\Delta b)^2-(\Delta C)^2)$½

S_H, and S_C are functions only of C_A and H_A, linear in C_A, and periodic in H_A; and S_L is a constant

In some situations, the added trap color will be placed side by side with the misregistration-caused colors. Generally, there is little concern with the visibility of misregistration-induced colors against the trap color because this will be two very thin lines against each other, and it will be harder to see than one of the lines against a solid, which we assume the pair color to be.

It will sometimes be the case that, due to the printer technology used, the required trapping is anamorphic (that is, its behavior in one dimension is different from that in another) in nature. For example, it could be the case that a trap region required is twice as large in one direction, as in the other, because of the printing process direction. In such a case, the trapping positional values can be scaled independently in each direction. Thus, in a vector-based technique, all of the coordinates in the geometric description would be scaled by a factor (e.g. 2) in one dimension before trapping regions are calculated, and then all coordinates (including those of trapping regions) would be scaled down by the same factor, restoring the original geometry, but making trap regions that are thicker in one dimension than the other.

Alternatively, an edge following process may be used with raster input, in which an edge following function is used. Here, the standard practice is that the offset edge is displaced a constant distance along the vector normal (perpendicular) to the edge being followed. A coordinate transformation can be applied to the offset edge (in the example of trapping twice as wide in x, scale the normal by 2 in x). This will cause the offset edge to be displaced further from vertical edges than from horizontal edges, with a smooth variation in between.

Finally, a windowing process might be used, or a morphological operator, with a window and its associated filters of morphological operator being appropriately scaled.

Another possible embodiment of the invention is in a lookup table (LUT) accessible by a computing device, either general or special purpose. In accordance with another aspect of the invention, FIG. **8** illustrates a system similar to the one shown in FIG. **3**, but better illustrating the possibility that IPU relies on a LUT storing trapping parameters. The goal with this method is to construct a table which, given colors A and B in CMYK space will produce a Boolean flag, and if the flag is true, a new color to be drawn between A and B. The flat will be false if the colors, when misregistered, will produce no visible artifact, e.g. (0,0,0,0) against anything; or there is no way of reducing the visibility of the artifact by interposing a third color.

As above, initially, the visibility f potential misregistrations is checked, as in FIG. **4**, step **202**:

1) Apply the method above to determine whether to trap. If the decisions is not to trap,

2) Set a Boolean flag to FALSE

3) Else

4) Go on to choose the color to insert between a,b

Choosing the color to insert between a and b, as in FIG. **4**, step **206**:

1. Apply the method above to find a trap color.
2. If the visibility of the selected trap color is worse than the initial misregistration visibility found earlier,
3. Set the flag to FALSE.
4. Otherwise
5. Set the flag to TRUE.
6. Store the difference between the color to insert and color A in the table.

To build a complete table, the first set of steps (visibility of misregistration) must be done for every pair of colors in color space. Half the color pairs are the mirror image of the other half, so it really only needs to be done for half of color space. If color space is quantized into n points, this is

1. STEP=1/n
2. HALFSTEP=STEP/2
3. STEPY=1/ny
4. HALFSTEPY=(STEPY)/2
5. for ac=HALFSTEP to 1-HALFSTEP by STEP
6. for bc=HALFSTEP to 1-HALFSTEP by STEP
7. for am=HALFSTEP to 1-HALFSTEP by STEP
8. for bm=HALFSTEP to 1-HALFSTEP by STEP
9. for ay=HALFSTEPY to 1-HALFSTEPY by STEPY

10. for by=HALFSTEPY to 1-HALFSTEPY by STEPY
11. for ak=HALFSTEP to 1-HALFSTEP by STEP
12. for bk=ak to 1-HALFSTEP BY STEP
13. check the visibility for (a,b)
14. if worst case visible
15. choose the color to insert
16. Store the difference between the color to insert and color A in the table.

Conveniently, this table can be built off-line. In a table-based approach all that is done at run time is indexing the table. Table indexing is performed as follow:

Given colors A and B, both in CMYK

1) Convert the separations of A and B to index space by multiplying them by a scale factor that puts them in the range 0.MAXINDEX.
2) Use the converted separations in an eight dimensional table lookup to find the color difference stored in the table.
3) Add the difference to color A giving the trap color.

If the value of MAXINDEX is one less than a power of two, and the colors are supplied as tuples of integers, this can be optimized using shifts and masks.

As always, there is a space-time tradeoff in indexing the table. If space is at a premium, one might consider interpolating between table entries, provided the entries vary sufficiently smoothly. This will increase the time required to find trapping information, but can reduce the table size substantially. For example, since the table is eight-dimensional, reducing the size by 20% in each dimension will reduce the size of the table to about 17% of its original size. Reducing the size by a factor of two in each dimension will reduce the total size by a factor of 256.

Of course, some practical optimizations are possible. The generation of class VisibilityVector is a relatively complex process as described. It needs to convert its two given colors to a useful color space such as CIELAB, and also all the misregistered colors. It must also find the C* and H* coordinates for every color it converts. The number of times through the inner loop (steps **13–16**) is the same as the number of color pairs for which the trapping information is computed. Thus there are tens of thousands to millions of color pairs. Each color pair needs to have both of its elements converted, and then all of its misregistration colors converted, before starting on step **15**. However, for n=8, and ny=4, there are only 83*4=2048 colors involved in all of these color pairs. This includes the colors generated by misregistrations. Assuming 4 unique colors generated by misregistering the average color pair, there are 14 million redundant color conversions done. Alternatively, a simple table lookup (4 dimensional) can get the misregistration colors converted, including to C* and H*. For the regular colors, if the table is generated in the order they are needed, a 1 dimensional lookup (i.e. pointer increment) will fetch the right color.

A similar optimization is available for the trap colors, but assuming the grid for them is different from the grid for color pairs, they will need their own table, again one-dimensional. If the trap colors are restricted to having their color components bounded by the color components of the color pair, then the grid for the trap colors must either be a multiple of the grid for the color pairs, or the process must find the nearest grid point for the conversion. A 16×16×16×16 table will prove acceptable.

A secondary table may be easily formed, using data from the primary table, storing frequently or recently used color pair trapping information. Smaller tables are faster to check than the larger tables. A table would also provide an excellent location for storing user specified values for selected trapping situations. The position of the trap color between 2 colors can be put into the table as well.

FIG. **9** is a simplified illustration of the results of trapping. Now the trap zone, between the cyan and red areas of the image, is characterized by having the trap color, selected to be between cyan and red. Of course, we placed the trap color pixels on one side or the other of the ideal edge, in accordance with the process of FIG. **7**.

it will no doubt be appreciated that several trapping processes have been described, each of which may be used together or independently of the other disclosed processes, should one choose to generate visibility criteria as part of the trapping process. Thus, for example the trapping position or location process described can be used irrespective of the particular trapping determination step, although it would be preferable to use it in a visibility based system, simply because the visibility criteria have already been calculated.

The disclosed method may be readily implemented in software using object oriented software development environments that provide portable source code that can be used on a variety of computer or workstation hardware platforms. Alternatively, the disclosed image processing system may be implemented partially or fully in hardware using standard logic circuits or specifically on a single chip using VLSI design. Whether software or hardware is used to implement the system varies depending on the speed and efficiency requirements of the system and also the particular function and the particular software or hardware systems and the particular microprocessor or microcomputer systems being utilized. The image processing system, however, can be readily developed by those skilled in the applicable arts without undue experimentation from the functional description provided herein together with a general knowledge of the computer arts.

While this invention has been described in conjunction with a preferred embodiment thereof, it is evident that many alternatives, modifications, and variations will be apparent to those skilled in the art. Accordingly, it is intended to embrace all such alternatives, modifications and variations as fall within the spirit and broad scope of the appended claims.

What is claimed is:

1. A method for optimizing rap selection for correcting for separation misregistration in color printing of a color image having at least two input colors (C_1,C_2),

a) generating a list of all unique colors appearing between colors (C_1) and (C_2) by processing all possible substitutions of a separation in color (C_1) with a separation in color (C_2);

b) sorting said list into an array of vectors considering two separations equal if they differ by less than a predetermined tolerance with an integer value assigned to each of said colors in said array thereby forming for each array entry an associated CMYK(C_1,C_2) color;

c) converting each element in said array of CMYK(C_1,C_2) colors from device coordinates into LAB-Vectors of device dependent color space each representing a list of possible misregistration of colors (C_1,C_2) in LAB-space;

d) constructing a visibility vector(C_1,C_2) for each input color (C_1,C_2) and for each element in said LAB-Vector computing a difference value from color (C_1) and from color (C_2) for that element and storing the minimum of these two differences corresponding to the visibilities of all of said misregistration colors;

e) for each entry in said visibility vector, if a maximum entry in said visibility vector is less than a threshold 't' then the corresponding misregistration will not be visible and no action need be taken at (C_1, C_2) otherwise if the maximum is greater than threshold 't' a candidate color for trapping is selected from a predetermined set of trapping colors maintained as a palette; and

f) determining if the visibility of said candidate color for trapping is worse than the initial misregistration visibility of step (d), and if so, then no trapping color is selected.

2. As in claim **1**, wherein said LAB-Vectors are constructed from device dependent color CMYK-Vectors generated from samples of CMYK colors from said device, organized into a table and mapped to LAB-Space.

3. As in claim **2**, wherein said LAB-Space is one of CIE-LAB space of CIE-LUV Space in order to take advantage of the correlation to visually perceptible color differences which allow said colors to be used to determine whether any specific color is likely to be visually perceptible, irrespective of the misregistration color; said visibility correlation usable as a metric as to how apparent a trap of trap modification can be.

4. As in claim **1** wherein said step of choosing a color to insert between (C_1) and (C_2), comparing every color 'T' in said color palette to CMYK(C_1,C_2) color and if 'T' is NOT between (C_1,C_2) then discarding 'K', and if 'T' is between (C_1,C_2) then, for each color 'T' for which CMY are between (C_1,C_2) generating a Trap-Visibility-Vector 'T_a' and a Trap-Visibility-Vector 'T_b' and determining therebetween a max visibility value 't-$_{max}$' in 'T_a, and 'T_b' to produce a visibility of *T' against color (C_1)* or color (C_2) with the lowest maximum visibility 'T_{min}' of all colors between (C_1) and (C_2) being representative of the best trapping color candidate to be selected.

5. As in claim **4**, if it is determined that the visibility of said candidate trapping color is NOT worse than the initial misregistration visibility of step (f), then choosing the candidate color 'T' whose worst visibility is the best of all the candidate trapping colors.

6. As in claim **4**, if it is determined that the visibility of said candidate trapping color is NOT worse than the initial misregistration visibility of step (f), then taking the sum of the squares of the visibilities over all misregistrations and choosing the candidate trapping color with the smallest sum.

* * * * *

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(12) United States Patent
Decker et al.

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(45) Date of Patent: *Mar. 6, 2001

(54) SYSTEM, METHOD, PROGRAM, AND PRINT PATTERN FOR PERFORMING REGISTRATION CALIBRATION FOR PRINTERS BY MEASURING DENSITY

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(*) Notice: This patent issued on a continued prosecution application filed under 37 CFR 1.53(d), and is subject to the twenty year patent term provisions of 35 U.S.C. 154(a)(2).

Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

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(51) **Int. Cl.**[7] **H04N 1/46**

(52) **U.S. Cl.** **358/504**; 358/1.9; 358/501; 347/19

(58) **Field of Search** 358/504, 501, 358/540, 1.9, 1.4, 502; 382/294, 287, 162; 347/19, 116, 248, 232; 345/431; 101/181, 170, 211; 399/49, 53–54

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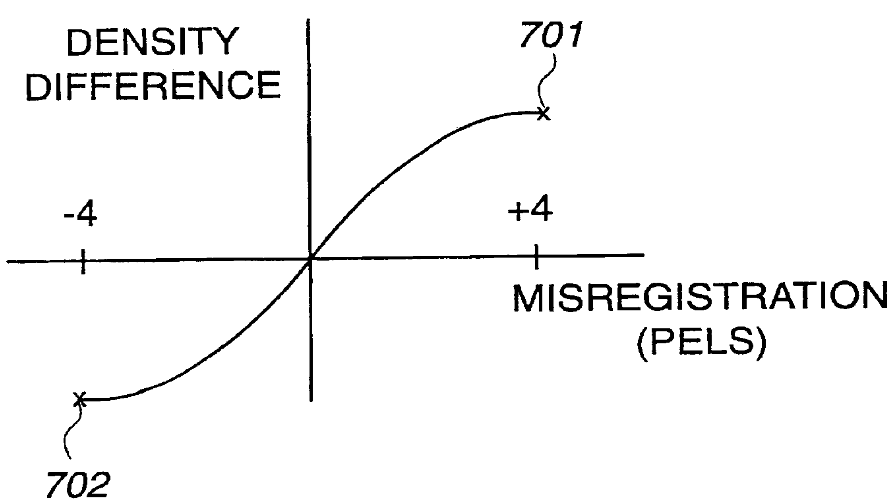
(57) **ABSTRACT**

The system, method, program, and print pattern of this invention allows print misregistration to be detected and controlled through density measurements. A special print pattern is used for which a correlation between a density measurement of the print pattern and an amount of misregistration can be made. Initially, for a given printer, and for each printing station within the printer, the special print pattern is printed using two printing stations at varying amounts of misregistration of one of the printing stations. The density of each special print pattern printed at the varied amount of misregistration is measured. A correlation is made between density and amount of misregistration of the one printing station relative to the other printing station. Whenever misregistration is desired to be determined, the special print pattern is printed, the density is measured, and the correlation is applied to the measured density to determine a misregistration amount.

30 Claims, 7 Drawing Sheets



Attachment E

US006198549B1

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Decker et al.

(10) **Patent No.: US 6,198,549 B1**
(45) **Date of Patent: *Mar. 6, 2001**

(54) **SYSTEM, METHOD, PROGRAM, AND PRINT PATTERN FOR PERFORMING REGISTRATION CALIBRATION FOR PRINTERS BY MEASURING DENSITY**

(75) Inventors: **William Chesley Decker**, Longmont; **Ho Chong Lee**, Boulder; **Jack Louis Zable**, Niwot, all of CO (US)

(73) Assignee: **International Business Machines Corporation**, Armonk, NY (US)

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(52) **U.S. Cl.** **358/504**; 358/1.9; 358/501; 347/19

(58) **Field of Search** 358/504, 501, 358/540, 1.9, 1.4, 502; 382/294, 287, 162; 347/19, 116, 248, 232; 345/431; 101/181, 170, 211; 399/49, 53–54

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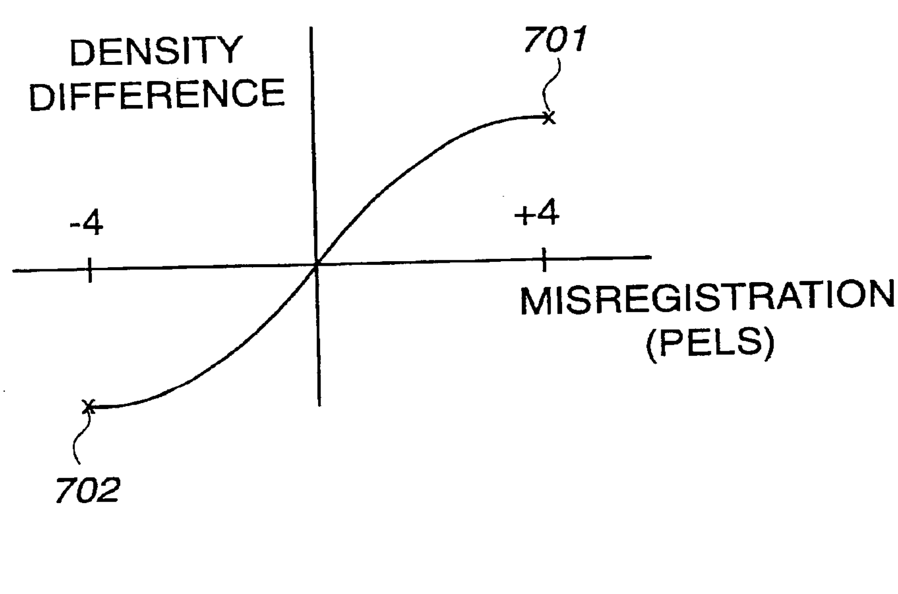
(57) **ABSTRACT**

The system, method, program, and print pattern of this invention allows print misregistration to be detected and controlled through density measurements. A special print pattern is used for which a correlation between a density measurement of the print pattern and an amount of misregistration can be made. Initially, for a given printer, and for each printing station within the printer, the special print pattern is printed using two printing stations at varying amounts of misregistration of one of the printing stations. The density of each special print pattern printed at the varied amount of misregistration is measured. A correlation is made between density and amount of misregistration of the one printing station relative to the other printing station. Whenever misregistration is desired to be determined, the special print pattern is printed, the density is measured, and the correlation is applied to the measured density to determine a misregistration amount.

30 Claims, 7 Drawing Sheets



Attachment E

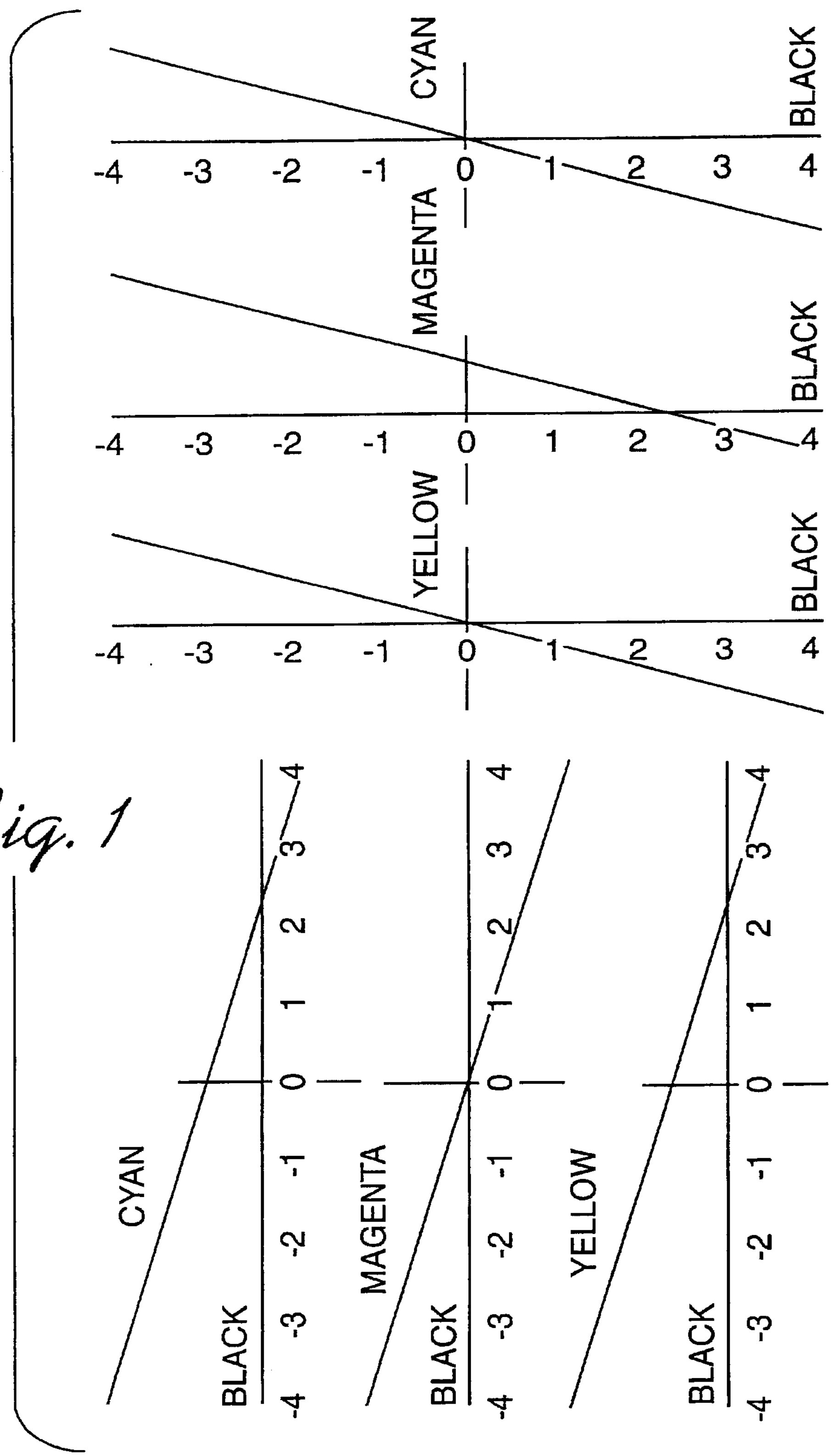


Fig. 1

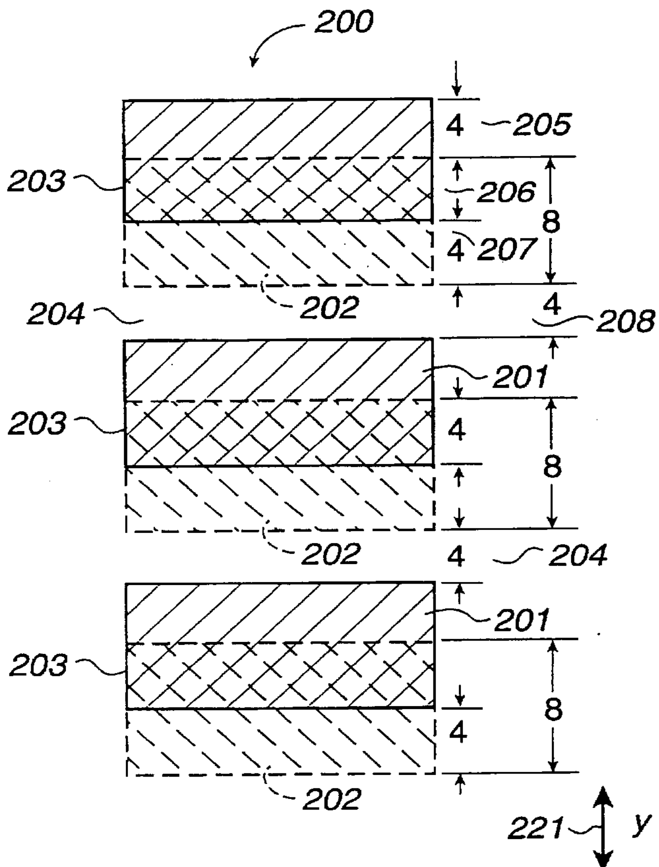


Fig. 2A

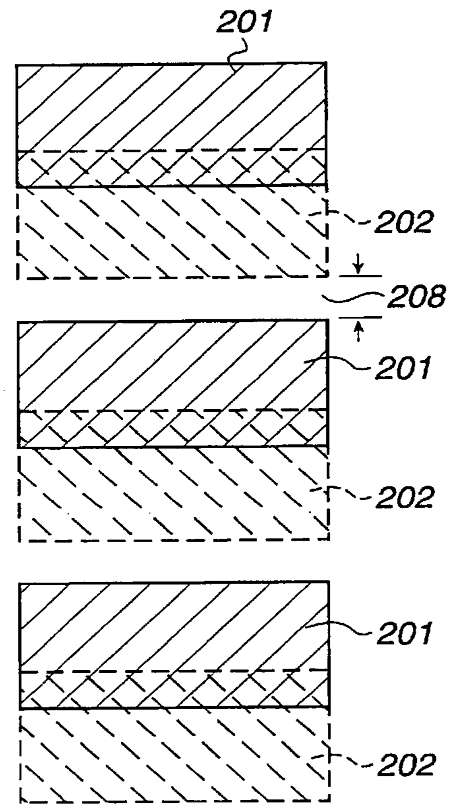


Fig. 2B

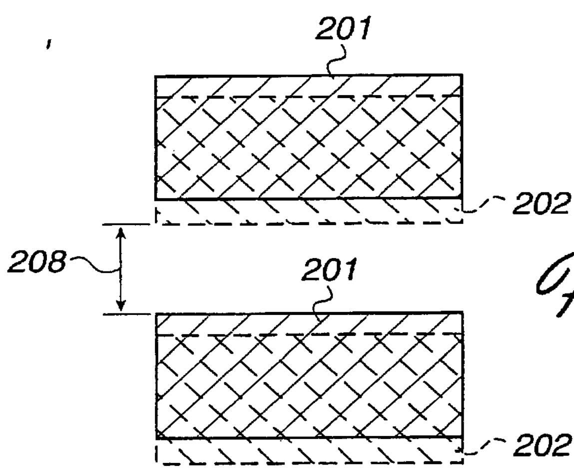


Fig. 2C

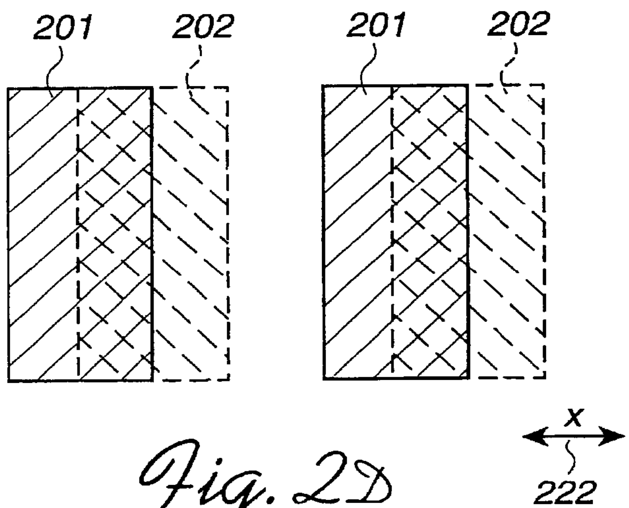


Fig. 2D

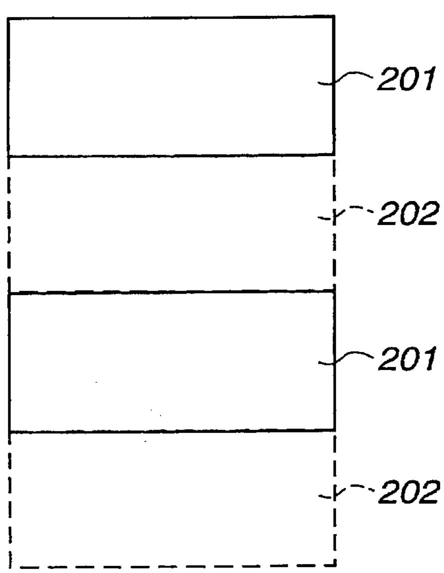


Fig. 2E

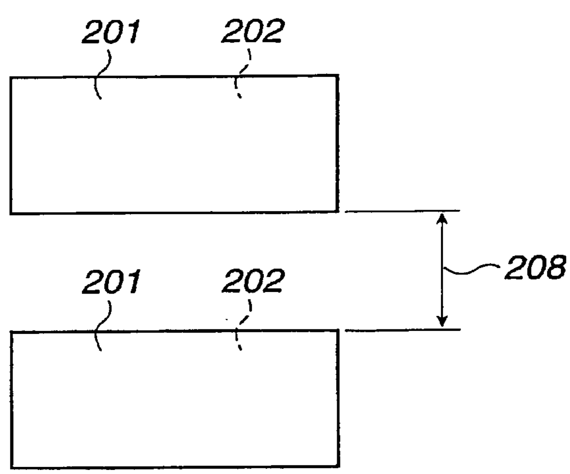


Fig. 2F

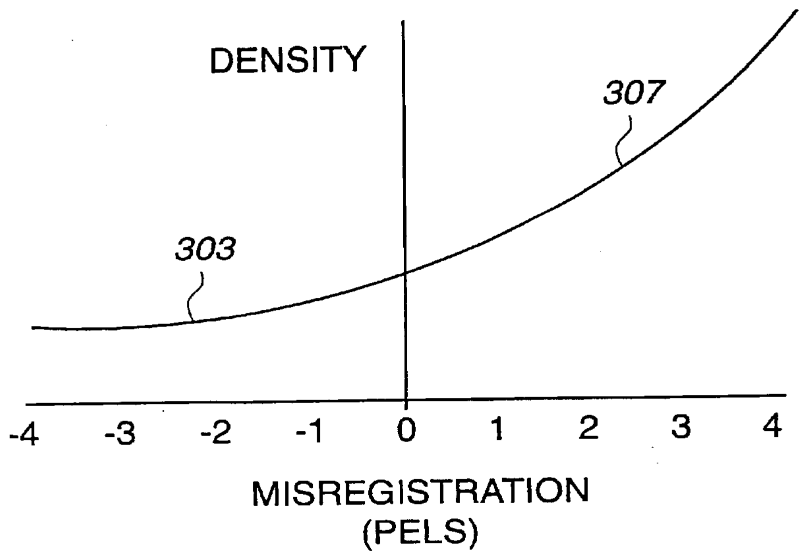

DENSITY
307
303
-4 -3 -2 -1 0 1 2 3 4
MISREGISTRATION
(PELS)

Fig. 3

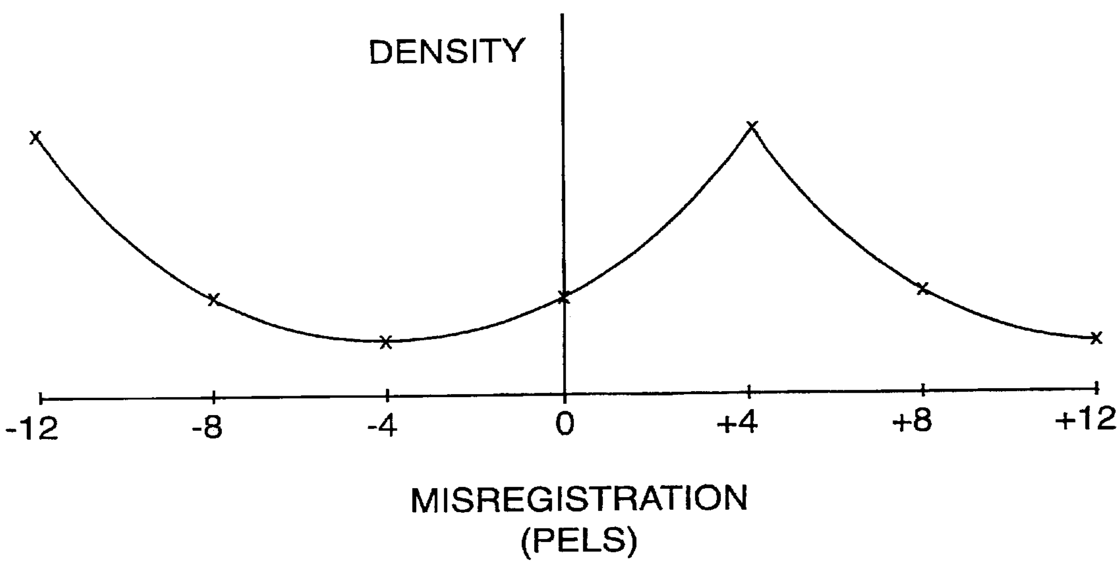

DENSITY
-12 -8 -4 0 +4 +8 +12
MISREGISTRATION
(PELS)

Fig. 4

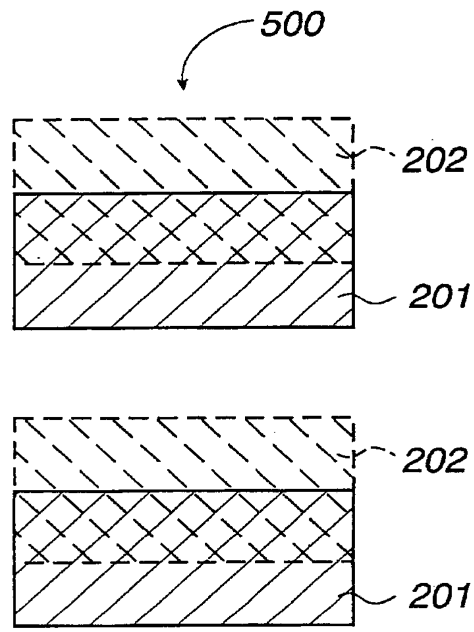

500
202
201
202
201

Fig. 5

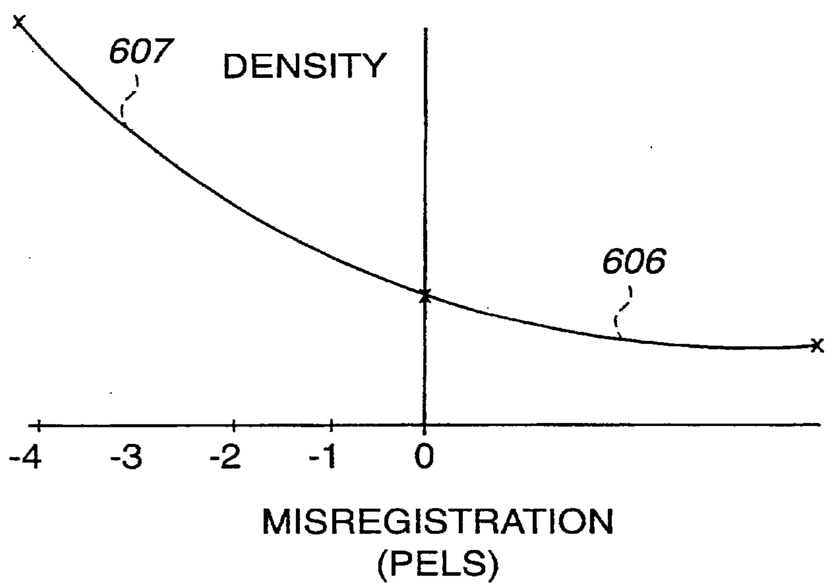

607
DENSITY
606
-4
-3
-2
-1
0
MISREGISTRATION
(PELS)

Fig. 6

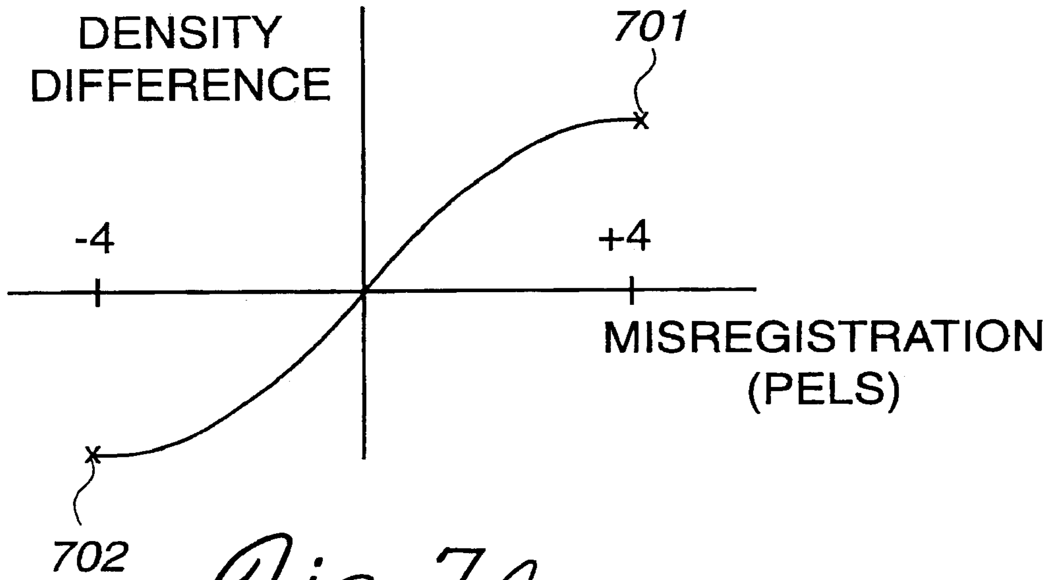

DENSITY
DIFFERENCE
701
-4
+4
MISREGISTRATION
(PELS)
702

Fig. 7A

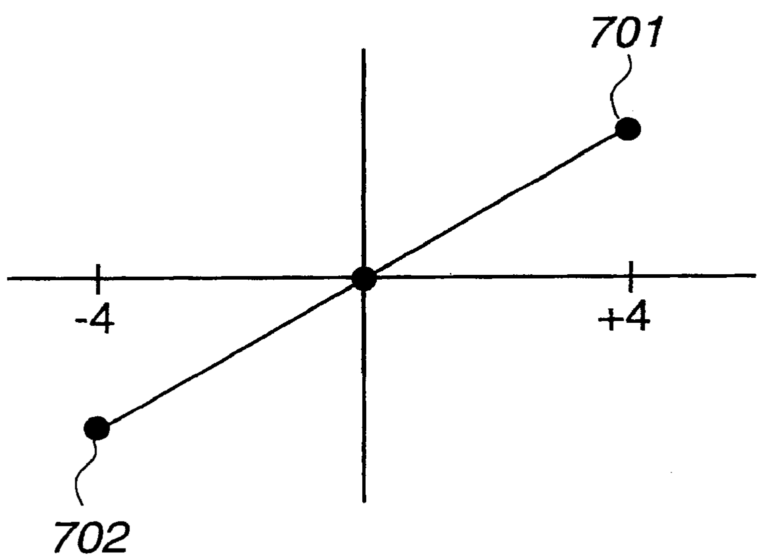

701
-4
+4
702

Fig. 7B

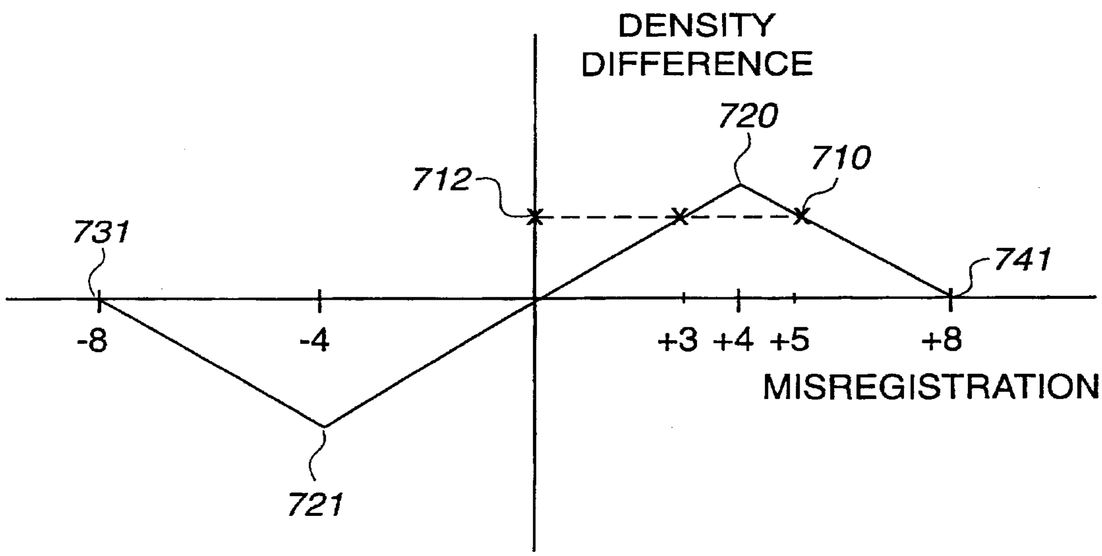

DENSITY
DIFFERENCE
720
710
712
731
741
-8
-4
+3 +4 +5
+8
MISREGISTRATION
721

Fig. 7C

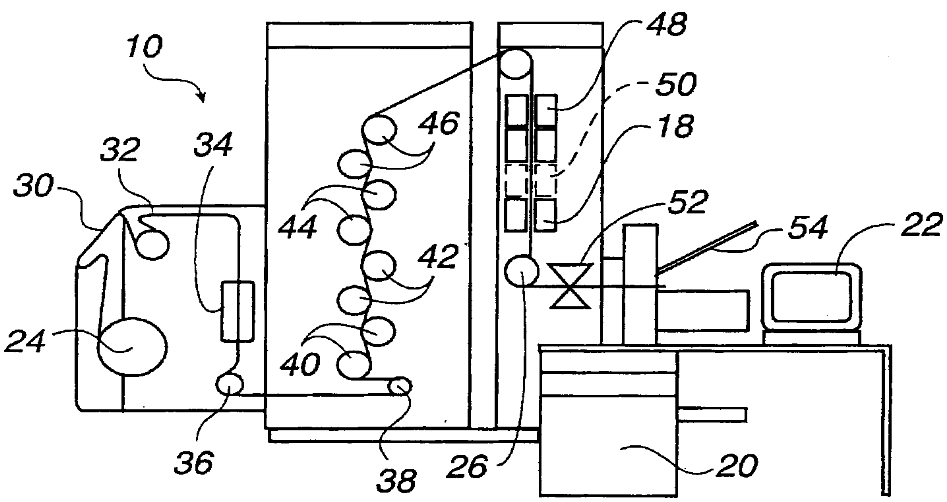

10
48
50
18
46
32
34
30
44
42
52
54
22
24
40
36
38
26
20

Fig. 8

SYSTEM, METHOD, PROGRAM, AND PRINT PATTERN FOR PERFORMING REGISTRATION CALIBRATION FOR PRINTERS BY MEASURING DENSITY

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates to the field of determining printing misregistration for printers, and more specifically, determining misregistration for each printing station in a printer having multiple printing stations.

2. Description of the Related Art

In order to ensure the best possible print quality from a printer, an operator typically will recalibrate the printer each day. Two of the most important factors that should be calibrated are density and registration. To calibrate the density, the operator will print out a control strip of the different colors (toners) used by the printer. The operator will then use a densitometer to measure the density of each of the patches in the control strip. Then, as a result of the density measurement reading of each of these patches, the operator will make some manual adjustments to the printer to correct for density in the different density ranges. Since maintaining optical density is a very important parameter that the operator needs to control for a printer, most operators have a densitometer for measuring the density.

Also, in a printing process, it is very important that all of the colors are correctly registered since colors are overlaid on top of each other to achieve a desired color as required in the subtractive printing process. If the colors are out of registration, a combination of colors will not lie directly on top of each other, and the quality of the color printing is distorted. In summary, maintaining accurate registration is required to get good color fidelity.

In order to calibrate the printer for registration, the printer will also print out a pattern of very small intersecting lines as shown in FIG. 1. The patterns are used for the registration of each color of the printer, e.g., cyan, magenta, and yellow, relative to black. The patterns are printed in both the X-direction and the Y-direction to calibrate the registration in both of these directions. For a printer having three colors, e.g., cyan, magenta, and yellow, six targets will be printed: three horizontal and three vertical. A greatly magnified illustration of these targets is shown in FIG. 1.

Typically, one can only determine the point of intersection with the aid of an eye loop or by using expensive and sophisticated imaging equipment. Ideally, the line should intersect at 0. If the line intersects at +1, the operator has to adjust the registration of the printer to make a correction for +1. Using an eye loop involves a "manual" process of eyeballing whether registration is off by examining the targets of colors that are laid on top of one another. With the aid of an eye loop, it may be difficult to readily determine whether the registration is +1, +2, 0, −1, or −2. Typically, experienced operators can only achieve a registration accuracy within +1 or −1 pel. Basically, these patterns are very difficult to read. For example, typically all of the patterns together, shown in FIG. 1, would take up an area of only about 0.5×0.25 inches.

As a typical scenario, an operator will, on a daily basis, use a densitometer to measure printed patches for adjusting the optical density of the printer, and will use an eye loop to measure another group of patterns for adjusting the registration. The patterns, i.e., targets, are typical of what are used in the industry to measure registration and the eyeball is the

measuring device. Consequently, this registration process is totally nonautomated.

Although there are a variety of ways for determining misregistration, most of the currently known techniques are similar in that they all compare a line or dot to a reference line, as just described. Then, corrections are made based upon a difference in location with respect to an ideal value or reference distance. The measurement of this variation from the reference distance can be done in an automated manner via sophisticated and expensive image analyzer equipment, or done in a nonautomated manner via the use of a microscope or the equivalent. It may not be cost justified to use expensive image analyzer equipment for determining misregistrations in a relatively low-cost printer. On the other hand, the inaccuracies and lack of ease of use of the manual determinations may not be sufficient, either.

SUMMARY OF THE INVENTION

It is, therefore, an object of this invention to maintain registration for optimizing color fidelity and crispness of a printed image including when an image is made by printing overlapping colors from multiple printing stations.

It is a further object of this invention to determine misregistration without relying on an "eyeball" measurement, and without using expensive and sophisticated equipment.

The system, method, program, and print pattern of this invention allow print misregistration to be detected and controlled by measuring density values using an optical densitometer. In one embodiment, the output of the densitometer is tied into the printer control panel and logic. In other embodiments, the densitometer can be used manually by an operator, in which case the operator will input the density results into the printer for automatic registration adjustment, or the operator will determine the resulting misregistration and make the adjustments manually on the printer. Special print patterns are used that have an output density that can be direly related to the amount of misregistration.

The special overall composite print pattern consists of a first repeating pattern of a printed horizontal bar having a specified width (e.g., 8 pels in the preferred embodiment) followed by a white space having, preferably, but not necessarily, the same specified width. The bars are printed by a first printing station, e.g., for the color black. Superimposed on this repeating pattern printed by the first printing station, but offset in a downward direction by half the width of the bars, is another repeating pattern, printed by another print station, e.g., for the color magenta, of a printed bar followed by a white space, all of which, preferably, but not necessarily, have the same specified width. The second repeating pattern is similar to the first repeating pattern described above except that the superimposed pattern is offset in the opposite direction than the offset direction in the first repeating pattern. This describes the overall composite print pattern for a nominal setup.

The above-described overall composite print pattern is used to determine misregistration in the vertical direction. To determine misregistration in the horizontal direction, a similar overall composite print pattern is printed except that the bars are vertical and the superimposed offsets are in the horizontal direction. A set of these overall composite print patterns, for determining both horizontal and vertical misregistration, are printed using each printing station to determine the misregistration of each printing station.

Initially, for a given printer, and for each printing station therein, the above-described overall composite print pattern,

having a first and second repeating pattern, is printed at varying incremental amounts of misregistration, including zero pel misregistration as determined by previously known methods. The optical densities of the first and second repeating pattern are measured using a densitometer. The optical density of the second repeating pattern is then subtracted from the optical density of the first repeating pattern to obtain a density difference for each incremental amount of misregistration. A correlation between density difference and amount of misregistration is then determined for the given printer and, if necessary, for each printing station therein, for each horizontal and vertical direction.

Once the correlation is determined, the misregistration at any given time can be determined for each direction and for each color by 1) printing an overall composite print pattern; 2) measuring the optical densities of the first repeating pattern and the second repeating pattern with a densitometer; 3) subtracting the measured optical density of the second repeating pattern from the first repeating pattern to get a density difference; 4) using the above determined correlation to determine a misregistration amount, i.e., a change in registration needed to correct the misregistration; 5) if the misregistration from step 4 is not acceptable, continuing to step 6, otherwise stopping, and 6) making the registration correction according to the misregistration amount and returning to step 1.

BRIEF DESCRIPTION OF THE DRAWING

For a more complete understanding of this invention, reference is now made to the following detailed description of the embodiments as illustrated in the accompanying drawing, wherein:

FIG. **1** illustrates registration targets used in previously known methods;

FIG. **2**A illustrates a first repeating pattern, having a repeating color bar and white space superimposed, with an offset in the upward direction, on top of a repeating black bar and white space, all of specified widths, of the overall composite pattern for measuring misregistration in the vertical direction;

FIG. **2**B illustrates a misregistration by 2 pels in the upward direction of the first repeating pattern;

FIG. **2**C illustrates a misregistration by 2 pels in the downward direction of the first repeating pattern;

FIG. **2**D illustrates a first repeating pattern, having a repeating color bar and white space superimposed, with an offset in the leftward direction, on top of a repeating black bar and white space, all of specified widths, of the overall composite pattern for measuring misregistration in the horizontal direction;

FIG. **2**E illustrates a misregistration by 4 pels in the upward direction of the first repeating pattern;

FIG. **2**F illustrates a misregistration by 4 pels in the downward direction of the first repeating pattern;

FIG. **3** illustrates a characteristic curve of density versus misregistration of the first repeating pattern of the overall composite pattern;

FIG. **4** illustrates the characteristic curve of FIG. **3**, including when misregistration is beyond +4 or −4 pels;

FIG. **5** illustrates a second repeating pattern, having a repeating color bar and white space superimposed, with an offset in the downward direction, on top of a repeating black bar and white space, all of specified widths, of the overall composite pattern for measuring misregistration in the vertical direction;

FIG. **6** illustrates a characteristic curve of density versus misregistration of the second repeating pattern of the overall composite pattern;

FIG. **7**A illustrates a characteristic curve of the density difference when the density of the second repeating pattern is subtracted from the density of the first repeating pattern;

FIG. **7**B illustrates a linearization of the characteristic curve shown in FIG. **7**A;

FIG. **7**C illustrates a linear curve of the density difference between the first repeating pattern and the second repeating pattern of the overall composite pattern for various amounts of misregistration; and

FIG. **8** is a block diagram of a printer.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

The preferred embodiment of the invention is used in conjunction with an IBM 3170 high-speed color printer. However, the invention can be used in connection with any printer.

The preferred embodiment of the invention carries out the registration process by using a device that measures density, e.g., a densitometer. Such a device, typically, will be available to an operator performing the registration process since the same operator, typically, will be calibrating the density, also, for which a densitometer is required.

Merely by using a densitometer to click on a pattern, as defined by this invention, the density reading will convey to the operator the amount of misregistration.

The basic pattern **200** is shown in FIG. **2**A. It should be noted that although this is the pattern used in this preferred embodiment, other patterns could be used. First, a reference color, e.g., black, bar **202**, having a specified dimension, is printed. Then another bar **203**, having a specified dimension, of a color, for which registration is being measured, is superimposed on top of the black bar, but it is displaced by a certain amount. In the preferred embodiment, each one of these bars is eight pels in the Y-direction **221**. A pel is essentially a dot of toner/ink. In a 600 pels/inch printer, the approxmate distance between adjacent pels is 0.00167 inches. A printed dot is larger than a pel by about 30% to 40% so that the printed dots will overlap. Therefore, an 8-pel width will be slightly wider than (8 * 0.00167) or 0.01336 inches. The superimposition **203** is a 4-pel overlap. A 4-pel white space **204** is left after printing another 8-pel black bar **202** which is also superimposed by an 8-pel color bar **201**, offset by four pels. The black bar and white space pattern with the superimposed, but offset, color bar and white space pattern is repeated.

The black pattern **202** is eight pels on, eight pels off, and eight pels on. The color, e.g., cyan, pattern **201** is eight pels on, eight pels off, and eight pels on, but it is displaced from the black pattern by four pels. As such, there will be four pels **207** of just black **202**, four pels **206** of black with a color superimposed on top of it, four pels **205** of just the color, and four pels **208** of white space. This pattern, as shown in FIG. **2**A, represents a nominal condition if each color, including black, is perfectly registered in the Y-direction **221**.

FIG. **2**B illustrates what happens if the color, e.g., cyan, is misregistered in the upward Y-direction by two pels. The cyan bar relative to the black bar is now moved up by two pels in each repetitive portion of the pattern. The white space **208** is no longer four pels, it is now only two pels. Therefore, the overall optical density of this pattern is going to increase because there is less white space.

FIG. 2C illustrates another case where the color is misregistered downward in the Y-direction by two pels from the nominal. In this case, a greater white space **208** is exposed. Because of this, the optical density will be lower for the misregistration pattern of FIG. 2C than for the nominal registration pattern of FIG. 2A.

A similar pattern, as shown in FIG. 2D, is used to determine misregistration in the X-direction **222**.

If the color is misregistered upward by +4 pels, as shown in FIG. 2E, the color bar will totally cover the white space of the nominal pattern shown in FIG. 2A. A +4 pel misregistration will basically result in the darkest pattern, i.e., the highest optical density. On the other hand, if the color was misregistered downward by 4 pels, as shown in FIG. 2F, the color bar would completely overlap the black bar, leaving the largest white space **208**. This would give the lowest optical density.

The characteristic curve of density versus misregistration for this type of pattern is shown in FIG. **3**.

Although any size pattern could be used in an embodiment of this invention, the 8-pel pattern described above was chosen for the preferred embodiment for the reasons described below. As the printer is printing out the repetitive test pattern, there will be some variation in registration as the paper is moving through the print station. Therefore, the density readings may not be truly indicative of the average misregistration. If the dimensions of the bars are too fine, e.g., two pels, the misregistration readings may only be applicable for that point in time and will not be an accurate assessment of the average overall misregistration. On the other hand, if the dimensions of the bars are large, e.g., sixteen pels, the aperture of the densitometer may not be large enough to get an accurate reading. That is, if the aperture of the densitometer had a diameter equivalent to the size of 16 pels, the readings from the densitometer would vary greatly depending upon where the densitometer was placed in the repetitive pattern, i.e., mostly over the white space, or an overlapped area, etc. Therefore, the bars in the repetitive pattern, and the amount of initial desired offset of the color bar from the black bar, should be of such a dimension to avoid any inaccuracies due to the placement of the aperture of the densitometer within the repetitive pattern, and to avoid inaccuracies due to density variations caused by variations in the paper velocity through the print station. Also, the minimum distance the pattern should be repeated should be such that there are enough repeated pattern sequences to completely fill the aperture of a densitometer that is being used to measure its density. Likewise, the length of the bars should be longer than the corresponding dimension of the aperture of the densitometer being used.

Also, the width of the bars also determines how far off registration can detect. For example, if the color bar **201** was off registration by +8 pels from the nominal pattern of FIG. 2A, the resulting repeating pattern would appear the same as that shown in FIG. 2A. In other words, the characteristic curve of FIG. **3** becomes that as shown in FIG. **4** when misregistrations of greater than +4 pels or −4 pels are taken into account. This characteristic curve will also continue to repeat with greater amounts of misregistration, as initially shown in FIG. **4**.

As shown in the curve, the amount of misregistration can only be uniquely determined if the misregistration is limited to being within +4 pels or −4 pels. For a misregistration greater than 4 pels in either direction, a given density reading will not uniquely determine the amount of misregistration. As such, a smaller bar dimension will result in a smaller amount of misregistration that can be uniquely determined with a given density reading. For example, a 4-pel bar would have a curve similar to that shown in FIG. **4**, except that the limits of misregistration would occur between −2 pels and +2 pels instead of −4 pels and +4 pels as shown for the 8-pel bar. Therefore, the larger the width dimension of the bar, the broader the width is of misregistration that can be detected uniquely.

As such, there are two factors that should be considered in determining the width of the bars used in the repeating pattern. First, the aperture of the densitometer limits how great the width can be, and the amount of misregistration that can be accurately or uniquely determined limits how small the width of the bar can be.

Taking into consideration that misregistrations typically occur within +4 pels or −4 pels for typical daily variations for the specific printer being used herein, and taking into consideration the aperture size of the densitometer being used, the width of each of the bars for the repetitive pattern was chosen to be 8 pels for this preferred embodiment.

There are several ways to determine what the density should be if there is perfect registration (a misregistration of 0 pels). First, one could initially take data by repeating the nominal case when the printer's registration and density is calibrated by using a previously known technique. The average density of all of these nominal test cases should give a close enough measurement of the density with 0 pel misregistration.

Another technique, and the one used in the preferred embodiment, is to print out two repeating patterns, with the color bar offset in the opposite direction for each repeating pattern. The density measurements of the patterns are then subtracted from each other. This is further described in more detail below.

The first basic composite pattern has been shown and described with reference to FIGS. **2A**, **2B**, **2C**, **2E**, and **2F**. FIG. **3** shows the density variation from measuring the registration output with a densitometer using the basic pattern of these figures.

The second repeating pattern is shown in FIG. **5**. Instead of offsetting the color bar upward from the black bar, as in the first pattern, the color bar is offset downward from the black bar. Again, it is an 8-pel pattern.

Using this second repeating pattern **500**, if the color bar is misregistered in the upward direction, more white space is exposed and the density will be lower than the density for the nominal case. This is just the opposite of what will happen if the first pattern **200**, FIG. **2A**, is used. The characteristic curve of density versus misregistration for this second repeating pattern **500** is shown in FIG. **6**, which is the mirror image of the curve shown in FIG. **3**.

If the optical densities that are measured by using the second pattern are subtracted from the optical densities that are measured using the first pattern, the resulting characteristic curve becomes a slight "S" curve representing density difference versus misregistration, as shown in FIG. **7A**. For convenience, and with insignificant resulting error, this curve can be estimated to be a linear line as shown in FIG. **7B**. It should be noted that the curves and graphs illustrated herein are merely representative of the type of results that can be expected from the data. Actual curves and graphs can be easily achieved by plotting the actual measurements taken for a given printer and toner, etc.

From the curves of FIG. **7A** or FIG. **7B**, one can determine a misregistration of 0 pels, i.e., nominal, because the two patterns will have a density difference of 0. At nominal, there

will be the exact same amount of white space, and the exact same overlap of bars (except in opposite directions), so the optical densities should exactly subtract from each other.

Likewise, at a misregistration of +4 pels for the first pattern, the density may be measured to be of 1.4, but for the second pattern, the density may be measured to be 0.4. The difference of 1 is shown as point **701** for the curves of FIG. 7A and FIG. 7B. At a misregistration of −4 pels for the first pattern, the density may be measured to be 0.4, i.e., it should be the same density as that measured for the second pattern having a misregistration of +4 pels. Again, for the second pattern, for a misregistration of 4 pels, the density should be measured to be the same as that measured for the first pattern having a misregistration of +4 pels, e.g., having a value of 1.4. The difference of −1 is shown as point **702** for the curves of FIG. 7A and FIG. 7B.

Therefore, the density difference is the result of subtracting the density of one pattern from the density of the other pattern, and it is related to misregistration as shown by the characteristic curves represented by FIG. 7A or FIG. 7B. FIG. 7B (or FIG. 7A) illustrates the basic relationship between density difference and misregistration. FIG. 7C shows an extension of the curve of FIG. 7B beyond +4 pels and −4 pels of misregistration. The curve is symmetric and it will continue to repeat itself as misregistration gets farther out.

The overall accuracy is improved by using both patterns to find a density difference versus misregistration. This is because any one pattern, the first pattern or the second pattern, has a relatively flat portion of its characteristic curve as shown by region **606** in FIG. 6 and region **303** in FIG. 3. By using the density difference, the extent of the flat portion of the curve is reduced, as shown by the curve of FIG. 7A, and is eliminated, as shown by the estimated linear curve of FIG. 7B. Finding the density difference by using both characteristic curves of FIG. 3 and FIG. 6 allows the "deep" portions of the curve, **307**, **607**, respectively, to have an affect throughout the whole misregistration range. Of course, greater accuracy and sensitivity can be achieved from a given density reading when the curves are more steep than flat. By using the density difference from both patterns, one can achieve acceptable sensitivity throughout the whole range.

For the particular printer used in conjunction with the preferred embodiment of this invention, the printer specification suggests that the registration be maintained within +2 or −2 pels. Basically, the operator can do that, even using the previously known techniques for maintaining registration. It is estimated that by using this invention, an operator can adjust the registration to within a half of a pel or a quarter of a pel of nominal. This assumes, of course, that the printer has the appropriate sensitivity in its controls to allow this fine amount of adjustment.

It should be noted that changes to this preferred embodiment could be made to achieve various amounts of registration accuracy, e.g., even within a tenth of a pel, as required for any given printer by varying the width of the pattern used and/or the size of the aperture of the densitometer.

As mentioned above, the registration is dynamic because the velocity of the paper moving through a printing station is not necessarily constant. The dynamic misregistration variations cannot readily be fixed unless there is a tight control on the velocity. Registration is affected by several factors, including velocity variation which an operator may have little control over. If the velocity variation will affect registration by +1 or −1 pel, then the print stations should be set up relative to each other to affect a misregistration that is equal to or better than +1 or −1 pel. The fact that the system, method, and print pattern of the preferred embodiment is capable of calibrating and adjusting the registration within plus or minus a half pel or a quarter of a pel is considered to be very good. Because the total misregistration is due to several factors, narrowing one of the factors to a significantly smaller variation can make the variations caused by the other factors, that are less capable of being controlled, more tolerable.

Additionally, the misregistration of each print station can be measured for each of n successive pages (where n is typically two). The resulting misregistration of each print station is averaged for the successive pages. Thus, this average misregistration will further minimize the error due to velocity variation.

Operation of the Preferred Embodiment

The system, method, program, and print pattern of the invention is carried out for a given printer as follows. For each direction (vertical and horizontal) and for each color (e.g., cyan, magenta, and yellow), the following operations are carried out. First, the two repeating patterns are printed out several times. Each time, the amount of misregistration is varied by a known amount. The optical density of each pattern is measured with a densitometer. The optical density measured for the second pattern is subtracted from the optical density measured for the first pattern for each group of patterns, where each one of the groups has a different amount of misregistration from another group, to determine the density difference for each given amount of misregistration. The misregistration is equal to a constant times the density difference.

$$\text{misregistration}=C_1 * (\text{density difference})$$

The above data (specified known amounts of misregistration and density difference) are used to calculate the constant C_1. For the particular printer used in this preferred embodiment, the constant is approximately four, and more exactly 4/1.1. The constant will also be influenced by the characteristics of the specific densitometer that is being used for measuring the density and the inks/toners that are used in the printer.

A series of curves is made from the data points from actually varying the registration. The constant is determined from the measurements taken. Essentially, the machine is misregistered +1, +2, +3, +4 pels, and −1, −2, −3, −4 pels. Both of the patterns are printed at each of these values, and the density differences are determined to get a characteristic curve. This curve is then used to get the constant.

The constant could be different for each color. For example, cyan, yellow, and magenta might have a different constant. However, in working with the preferred embodiment, the colors all had essentially the same constant. However, there is no guarantee that this would be the case for different setups, printer, toner/inks, pattern dimensions, etc.

Once the constant is determined, the constant is used to determine misregistration as follows. Assume, for example, purposes that the constant has a value of 4. Then the first pattern and second pattern are printed by the printer using the current printer setup for registration. Then the first pattern is measured for its density, and the second pattern is measured for its density. The difference between the two readings is then calculated. Assume, for example, the density difference is one-half. The density difference is multiplied by the constant to arrive at the amount of misregistration. In this example, the misregistration is 2 pels, i.e., 0.5 * 4=2.

A computer program is used in the preferred embodiment of this invention to help the operator step through the registration process described above. The program may itself be resident in a printer, such as a high-function printer. Such a printer may also have its own internal densitometer such that the patterns are printed and optically measured internally within the printer. The program in the printer would then calculate the amount of misregistration, as discussed above, and automatically adjust itself to correct for the misregistration. This is a fully automated registration process.

FIG. **8** is a block diagram of a printer **10** having an internal densitometer **18**. The printer shown also includes a paper reel **24**, splicing table **30**, paper drying roll **32**, paper cooling **34**, paper condition sensor **36**, speed motor **38**, printing stations **40**, **42**, **44**, **46**, fuser **48**, paper cooling **50**, torque motor **26**, cutter **52**, and stacker **54**. The printing stations **40**, **42**, **44**, **46** comprise front and back printing engines for the various colors of ink used by the printer, such as cyan, magenta, yellow, and black. For more colors of ink, additional pairs of print engines would be contained within the printing station. The display **22** displays information to the user, such as a determined misregistration amount. Input devices, such as touch screen, mouse, keyboard, etc. may also be connected to the printer to receive input from the user. The controller **20** contains the computer program, and the controller **20** can adjust the registration of the printing stations.

In a semiautomatic registration process, the densitometer and program may both be resident inside the printer, but the program will display to the user on a display screen attached to the printer the amount of adjustment that the printer needs. The operator would then make the adjustments manually on the printer. In another semiautomatic registration process, the densitometer may not be resident inside the printer, but may be external to the printer for use by the operator. The operator would then measure the optical densities and input the values into a computer program resident either in the printer or in a separate computer. The program would display to the user the amount of misregistration. The operator would then manually make the adjustment, such as through a control knob, button, panel, or instruct the printer to make the adjustment through an interface on the printer display panel.

It should be noted that the invention may also be carried out with the operator performing all of the calculations and manually adjusting the registration controls on the printer without the aid of any computer program.

For those embodiments using a computer program, the program receives as input the varying amounts of predetermined misregistration and the corresponding measured density values for the first pattern and the second pattern at each predetermined misregistration amount. The program then determines the density difference at each misregistration amount and the corresponding characteristic curve and the resulting constant for that set of input, i.e., for a color, direction of misregistration (horizontal or vertical), given printer, etc. Then, each time an operator desires to check the registration of the printer, the operator will have the printer print out the overall composite pattern, having a first and second repeating pattern, for each color and in each direction (horizontal and vertical). For each first and second repeating pattern printed, the density of each pattern is measured (either by a densitometer internal to the printer or by an operator using a densitometer) and these values (or the density difference values) are received as input by the computer program. The computer program will determine the misregistration using the constant that was determined from the initial calibration process.

The computer program will display to the operator the amount of misregistration, e.g., a 2-pel misregistration or a 2.2-pel nisregistration or whatever. For fully automatic embodiments, the program will then query the operator as to whether the operator wants the machine to correct itself automatically. If the operator inputs a "yes" indication, then the operator does not have to do anything else. For some results, the amount of misregistration may be so small (e.g., within a quarter pel or half pel) that it is not necessary to make any adjustments to the printer. The program contains an "if statement" to determine whether the misregistration is greater than a certain amount. If it is not, then no adjustments are made. If it is, then the adjustments are made, the two repeating patterns are reprinted using the new registration adjustment, the density difference is determined, and the constant is applied to determine a new misregistration amount, if any.

An aspect of the registration process is further described with reference to FIG. 7C. For example, assume that the actual misregistration was at +5 pels as shown at point **710**. The density difference reading is indicated by the reading at point **712**. The program would take this reading at point **712** and use the constant as calculated above to determine the misregistration to be +3 pels. The printer or operator would then make a +3 pel correction for misregistration. With this correction for a +3 pel misregistration, the "real" misregistration is now +2 pels. The registration process will then repeat itself, that is, both repeating patterns are printed and. the densities are measured. Now, this density difference and the known constant are used to determine the amount of misregistration which will, in this case, be the "true" misregistration. After the printer is adjusted to account for this amount of misregistration, the patterns are printed again, and the densities are measured, the density difference should now be zero (or near zero to account for some error) to indicate that the registration of the printer is correct.

Therefore, anything within +8 or −8 pels will ultimately be corrected accurately by this iterative process. The number of iterations that it will take will vary. For example, a density difference may indicate that the misregistration is +1 (when in fact it is really out of registration by +7 pels). A correction for +1 pel will get readings indicating a misregistration of +2 pels (when in fact it is now out of registration by +6 pels). A correction for +2 pels will get readings indicating a misregistration of +4 pels (which should reflect the actual amount of misregistration). After making the adjustment for +4 pels, the next readings should indicate a density difference of zero.

If the misregistration is actually within +4 or −4 pels, only one iteration for correction should be necessary. If the misregistration is actually off by more than 4 pels (+4 or −4), but less than 8 pels (+8 or −8), then there may need to be two, three, or more iterations made before the misregistration is totally corrected.

As noted earlier, the curve of FIG. 7C continues on out in a repeating fashion beyond +8 and −8 pels. The program would need to be limited to only performing corrections within +8 or −8 pels. This limitation may be more than enough for some printers that may rarely, if ever, get out of registration by more than +8 or −8 pels. If a larger range was needed for a specific printer, the width of the pattern bars could be increased from 8 pels to 16 pels, as discussed previously. The characteristic curve would still be the same as shown in FIG. 7C, except that the +4 and −4 pel values would be +8 and −8 pels and the +8 and −8 pel values would

be +16 and −16, respectively. Ideally, at least the majority of the misregistrations should fall into the middle half of this range so that the processing can take place entirely along the curve in FIG. 7C between points **721** and **720**. As discussed above, increasing the width of the pattern bar to 16 pels, or other value, may introduce error depending upon the aperture size of the densitometer and the placement of the densitometer on the repetitive bar pattern. If a 16-pel-width bar pattern is needed to accommodate greater misregistrations, a densitometer with a larger aperture size could be used. In some situations, this may be difficult to implement if the operators already have a certain densitometer with a given aperture size that they use.

By limiting the program to correcting misregistrations within the range between **731** and **741** on the curve shown in FIG. 7C, then the above iterative process can be enhanced by adding some value checking within the program. For example, if the density difference indicated a misregistration of −1 pel, then after a correction for −1 pel, the next density difference should approach zero if indeed the misregistration was only off by −1 pel. However, if the actual misregistration was −7 pels, then the next density difference would have a greater negative value than the previous reading. The program could detect this and realize that the first reading must have been indicative of the area of the curve around −7 pels instead of −1 pel. The program would then adjust for that and indicate a misregistration of −7 pels. After adjustment for this amount of misregistration, the next density difference should indeed indicate a value of zero or close to it within an acceptable amount of error. Adding some checks into the program to analyze the direction the density difference is moving in response to misregistration adjustments can possibly eliminate some intermediate iterative steps.

Another feature of the program allows the operator to override the suggested misregistration correction. This allows the operator to manually make another adjustment or to tell the printer to make another misregistration adjustment if the operator suspects the actual misregistration is different from what the program initially indicates. This can also reduce the number of iterative steps needed to get the printer into registration.

It has been found that no error is created if the optical densities are not at the nominal value. If the optical density of the printer is out of the specification range, i.e., too high or too low, this does not affect the registration process described herein. In experimenting with the preferred embodiment of this invention, the optical densities were varied +20% and −20%, which are greatly out of the specification range. Even with this great amount of optical density variations, the constant C_1 had the same value. As such, registration can be corrected as described herein even if the optical densities are not correct. In previous registration techniques, optical density was not a concern since registration was determined by measuring line offsets by eye using an eye loop. Since the invention described herein measures registration by measuring density with a densitometer, optical density of the machine was an initial factor that had to be considered. However, the registration process described herein is insensitive to the optical density being printed by the printer, even though the registration process involves density measurements.

It should be noted that although the above preferred embodiment addressed misregistrations of various colors (e.g., cyan, magenta, and yellow) with respect to black, the invention can also be used to register two lines of the same color, e.g., black. For example, two laser beams can be lined up so that a first laser beam prints the first pel row and the second laser beam prints the second pel row. The invention disclosed herein, i.e., of using a densitometer to measure registration, can be used to get very tight registrations between the two.

Using the foregoing specification, the invention may be implemented as a machine, process, or one or more articles of manufacture (including the print pattern on a medium used by a printer and a computer program on a computer-usable medium) by using standard programming and/or engineering techniques to produce software, firmware, hardware, or any combination thereof Any resulting program(s), having computer-readable program code, may be embodied within one or more computer-usable media such as memory devices or transmitting devices, thereby making a computer program product or article of manufacture according to the invention. As such, the terms "article of manufacture" and "computer program product" as used herein are intended to encompass a computer program existent (permanently, temporarily, or transitorily) on any computer-usable medium such as on any memory device or in any transmitting device.

Executing program code directly from one medium, storing program code onto a medium, copying the code from one medium to another medium, transmitting the code using a transmitting device, or other equivalent acts may involve the use of a memory or transmitting device which only embodies program code transitorily as a preliminary or final step in making, using, or selling the invention.

Memory devices include, but are not limited to, fixed (hard) disk drives, diskettes, optical disks, magnetic tape, semiconductor memories such as RAM, ROM, Proms, etc. Transmitting devices include, but are not limited to, the internet, intranets, electronic bulletin board and message/note exchanges, telephone/modem-based network communication, hard-wired/cabled communication network, cellular communication, radio wave communication, satellite communication, and other stationary or mobile network systems/communication links.

A machine embodying the invention may involve one or more printing systems and/or processing systems including, but not limited to, CPU, memory/storage devices, communication links, communication/transmitting devices, servers, I/O devices, or any subcomponents or individual parts of one or more printing systems and/or processing systems, including software, firmware, hardware, or any combination or subcombination thereof, which embody the invention as set forth in the claims.

One skilled in the art of computer science will easily be able to combine the software created as described with appropriate general purpose or special purpose computer hardware or printer hardware to create a computer/printer system and/or computer/printer subcomponents embodying the invention and to create a computer/printer system and/or computer/printer subcomponents for carrying out the method of the invention.

While the preferred embodiment of the present invention has been illustrated in detail, it should be apparent that modifications and adaptations to that embodiment may occur to one skilled in the art without departing from the spirit or scope of the present invention as set forth in the following claims. For example, some modifications and adaptations may include the following:

User input may be received from the keyboard, mouse, pen, voice, touch screen, or any other means by which a human can input data to a computer, including through other programs such as application programs;

any measuring device capable of measuring densities could be used;

- any type of pattern, including varying shapes and dimensions, could be used that was capable of indicating misregistration in terms of its optical density;
- pel sizes may vary depending on the specific printer being used;
- actual width sizes will also vary depending upon the size of the actual printed dots of a printer;
- although the color black was used herein as the reference color or the reference printing station, relative to which misregistration of the other colors or printing stations were determined, any color or printing station could be used as the reference color or reference printing station; and
- although the term "actual misregistration" may be used herein to indicate a present misregistration that is being determined, it may not be the "true" misregistration as further iterations may be needed depending upon where the measured density or density difference falls within the characteristic curve as described above.

We claim:

1. A method of determining misregistration of a printer, the method comprising:

   printing multiple instances of a first and second repeated patterns, wherein for each printing instance, the first and second repeated patterns are printed at a different predetermined misregistration;

   measuring densities of the first and second repeated patterns for each printing instance;

   determining a density difference for each printing instance by subtracting the measured density of the first and second repeated patterns for the printing instance;

   determining a characteristic curve providing a relationship of the determined density differences to the predetermined misregistrations;

   calculating a correlation from the determined characteristic curve, wherein the correlation is between the density difference and predetermined misregistration;

   printing at least one additional print pattern after calculating the correlation;

   measuring density of the at least one additional print pattern;

   determining an amount of misregistration by applying the correlation to the measured density of the at least one additional print pattern.

2. The method of claim 1, wherein applying the correlation to the measured density of the at least one additional print pattern comprises multiplying the correlation times the density of the measured at least one additional print pattern.

3. The method of claim 2, wherein the at least one additional print pattern comprises third and fourth print patterns, further comprising measuring a density difference of the third and fourth print patterns, wherein determining the amount of misregistration using multiplication is calculated as follows:

   correlation * (measured density difference of the third and fourth print patterns).

4. The method of claim 1, wherein the first and second print patterns are printed by a first and second printing stations, wherein the at least one additional print pattern is printed by the second printing station, and wherein the determined misregistration indicates misregistration for the second printing station.

5. The method of claim 1, wherein printing the pattern comprises printing the pattern on successive pages and

wherein measuring the density further comprises averaging the density over successive pages.

6. The method of claim 1, wherein the first print pattern, second print patter and at least one additional print pattern comprise a same pattern.

7. The method of claim 1, wherein the first print pattern and the second print pattern comprise a same print pattern.

8. The method of claim 1, wherein the first print pattern comprises

   a repeatedly printed first printed bar, wherein during each print repetition, the first printed bar is printed to have a first specified width of a first color from a first printing station, followed by a first space of a second specified width, and repeating the first printed bar and first space for at least a minimum distance; and

   wherein the second print pattern comprises a repeatedly printed second printed bar, wherein during each print repetition, the second printed bar is printed to have the first specified width of a second color from a second printing station, followed by a second specified width superimposed on the first printed bar and the first space but offset, by a predetermined amount in a predetermined direction, from the first printed bar and first space, and repeating the second printed bar and second space with the offset by the predetermined amount in the predetermined direction for the minimum distance;

   whereby superimposing and offsetting the repeatedly printed second printed bar and the second space on top of the first printed bar and first space results in a repeated white space pattern having a resulting width, wherein the resulting width is repeated between every two instances of the second printed bar superimposed on the first printed par.

9. The method of claim 8, wherein the first and second specified widths are small enough so that at least one complete pattern sequence of the repeating print pattern is smaller than an aperture of a densitometer used to measure density of the repeating pattern.

10. A system for determining misregistration of a printer, the system comprising:

   means for printing multiple instances of a first and second repeated patterns with the printer, wherein for each printing instance, the first and second repeated patterns are printed at a different predetermined misregistration;

   means for measuring densities of first and second repeated patterns for each printing instance;

   determining a density difference for each printing instance by subtracting the measured density of the first and second repeated patterns for the printing instance;

   determining a characteristic curve providing a relationship of the determined density differences to the predetermined misregistrations;

   means for calculating a correlation from the determined characteristic curve, wherein the correlation is between the density difference and predetermined misregistration;

   means for printing at least one additional print pattern after calculating the correlation;

   means for measuring density of the at least one additional print pattern; and

   means for applying the correlation to the measured density of the at least one additional print pattern to determine an amount of misregistration.

11. The printer of claim 10 wherein the means for applying the correlation to the measured density of the at

least one additional print pattern to determine the amount of misregistration comprises multiplying the correlation times the measured density of the at least one additional print pattern.

12. The printer of claim 11 further comprising means for causing an adjustment of registration as a result of the determined amount of misregistration.

13. The printer of claim 11 further comprising means for displaying the amount of misregistration.

14. The printer of claim 11 further comprising means for querying an operator whether the printer should automatically correct for misregistration by the determined amount of misregistration.

15. The system of claim 11, wherein the at least one additional print pattern comprises third and fourth print patterns, further comprising measuring a density difference of the third and forth print patterns, wherein the means for determining the amount of misregistration using multiplication uses the equation:

correlation * (measured density difference of the third and fourth print patterns).

16. The system of claim 10 implemented in a printer, wherein the means for measuring the print patterns comprises a densitometer in the printer, and wherein the means for using the measured densities to determine the amount of misregistration is implemented in a computer program resident in the printer.

17. The system of claim 10, wherein the first pint pattern, second print pattern and at least one additional print pattern comprise a same pattern.

18. The system of claim 10, wherein the first print pattern and the second print pattern comprise a same print pattern.

19. The system of claim 10, wherein the first print pattern comprises

a repeatedly printed first printed bar, wherein during each print repetition, the first printed bar is printed to have a first specified width of a first color from a first printing station, followed by a first space of a second specified width, and repeating the first printed bar and first space for at least a minimum distance; and

wherein the second print pattern comprises a repeatedly printed second printed bar, wherein during each print repetition, the second printed bar is printed to have the first specified width of a second color from a second printing station, followed by a second specified width superimposed on the first printed bar and the first space but offset, by a predetermined amount in a predetermined direction, from the first printed bar and first space, and repeating the second printed bar and second space with the offset by the predetermined amount in the predetermined direction for the minimum distance;

whereby superimposing and offsetting the repeatedly printed second printed bar and the second space on top of the first printed bar and first space results in a repeated white space pattern having a resulting width, wherein the resulting width is repeated between every two instances of the second printed bar superimposed on the first printed par.

20. A computer program, on a computer-usable medium, capable of causing a processor and printer to perform:

printing multiple instances of a first and second repeated patterns, wherein for each printing instance, the first and second repeated patterns are printed at a different predetermined misregistration;

measuring densities of the first and second repeated patterns for each printing instance;

determining a density difference for each printing instance by subtracting the measured density of the first and second repeated patterns for the printing instance;

determining a characteristic curve providing a relationship of the determined density differences to the predetermined misregistrations;

calculating a correlation from the determined characteristic curve, wherein the correlation is between the density difference and predetermined misregistration;

printing at least one additional print pattern after calculating the correlation;

measuring density of the at least one additional print pattern; and

determining an amount of misregistration by applying the correlation to the density of the at least one additional print pattern.

21. The program of claim 20, wherein applying the correlation to the measured density of the at least one additional print pattern comprises multiplying the correlation times the measured density of the at least one additional print pattern.

22. The computer program of claim 20, wherein the at least one additional print pattern comprises a third and fourth print patterns, further comprising measuring density difference of the third and fourth print patterns, wherein determining the amount of misregistration using multiplication is calculated as follows:

correlation * (measured density difference of the third and fourth print patterns).

23. The computer program of claim 20 wherein the computer program, on the computer-usable medium, resides in a printer.

24. The computer program of claim 20 wherein the computer program, on the computer-usable medium, resides in a computer external to the printer.

25. The computer program of claim 23, further comprising means for causing the printer to automatically adjust registration according to the determined amount of misregistration.

26. The computer program of claim 20 further comprising means for displaying the determined of misregistration.

27. The program of claim 20, wherein the first print pattern, second print pattern and at least one additional print pattern comprise a same pattern.

28. The program of claim 20, wherein the first print pattern and the second print pattern comprise a same print pattern.

29. The program of claim 20, wherein the first print pattern comprises

a repeatedly printed first printed bar, wherein during each print repetition, the first printed bar is printed to have a first specified width of a first color from a first printing station, followed by a first space of a second specified width, and repeating the first printed bar and first space for at least a minimum distance; and

wherein the second print pattern comprises a repeatedly printed second printed bar, wherein during each print repetition, the second printed bar is printed to have the first specified width of a second color from a second printing station, followed by a second specified width superimposed on the first printed bar and the first space but offset, by a predetermined amount in a predetermined direction, from the first printed bar and first space, and repeating the second printed bar and second space with the offset by the predetermined amount in the predetermined direction for the minimum distance;

whereby superimposing and offsetting the repeatedly printed second printed bar and the second space on top of the first printed bar and first space results in a repeated white space pattern having a resulting width, wherein the resulting width is repeated between every two instances of the second printed bar superimposed on the first printed par.

30. The program of claim **29**, wherein the first and second specified widths are small enough so that at least one complete pattern sequence of the repeating print pattern is smaller than an aperture of a densitometer used to measure density of the repeating pattern.

* * * * *

UNITED STATES PATENT AND TRADEMARK OFFICE
CERTIFICATE OF CORRECTION

PATENT NO. : 6,198,549 B1
DATED : March 6, 2001
INVENTOR(S) : William Chesley Decker

It is certified that error appears in the above-identified patent and that said Letters Patent is hereby corrected as shown below:

Column 14,
Line 4, please delete "patter" and insert -- pattern -- therefore
Line 34, please delete "par" and insert -- bar -- therefore

Column 15,
Line 59, please delete "par" and insert -- bar -- therefore

Column 16,
Line 25, please insert -- a -- between "measuring" and "density"
Line 42, please insert -- amount -- between "determined" and "of"

Column 17,
Line 7, please delete "par" and insert -- bar -- therefore

Signed and Sealed this

Thirty-first Day of May, 2005

Jon W. Dudas

JON W. DUDAS
Director of the United States Patent and Trademark Office

US005748221A

United States Patent [19]

Castelli et al.

[11] **Patent Number: 5,748,221**

[45] **Date of Patent: May 5, 1998**

[54] **APPARATUS FOR COLORIMETRY GLOSS AND REGISTRATION FEEDBACK IN A COLOR PRINTING MACHINE**

[75] Inventors: **Vittorio Castelli**; **Edward J. Solcz**, both of Yorktown Heights; **John J. Ricciardelli**, Poughkeepsie, all of N.Y.; **Harold Anderson**, Rancho Palos Verdes, Calif.; **Harold Brown**, New City, N.Y.

[73] Assignee: **Xerox Corporation**, Stamford, Conn.

[21] Appl. No.: **551,306**

[22] Filed: **Nov. 1, 1995**

[51] **Int. Cl.^{6}** **B41J 2/47**

[52] **U.S. Cl.** **347/232**; 358/518

[58] **Field of Search** 347/232; 358/501, 358/518, 523, 525; 399/101, 107, 109

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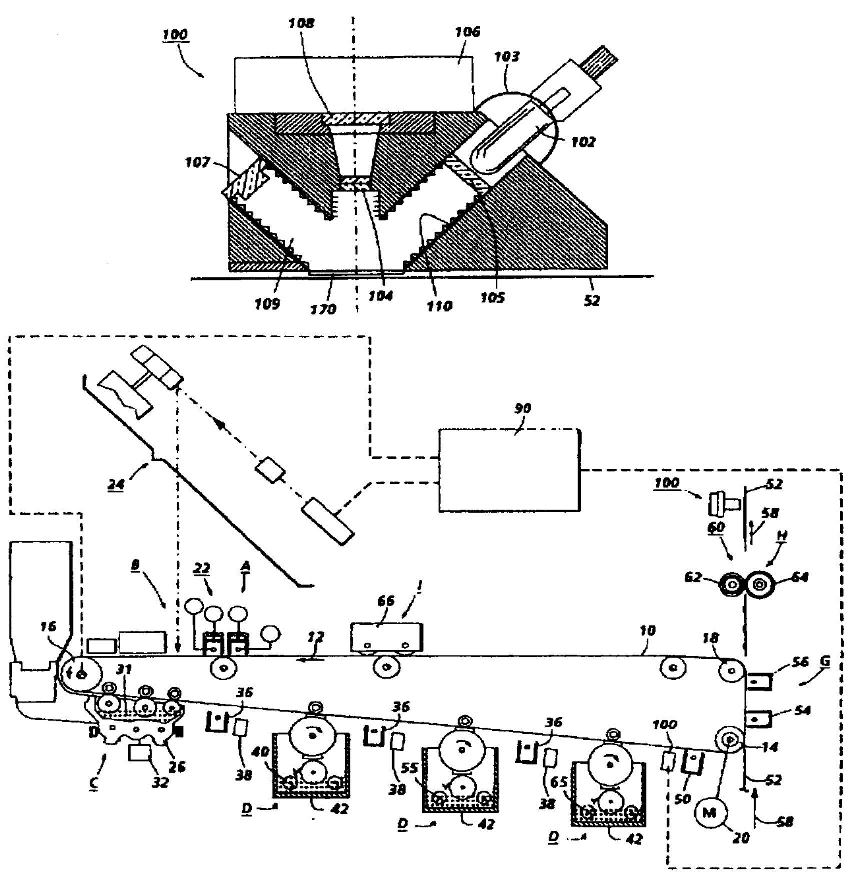
Primary Examiner—Mark J. Reinhart
Attorney, Agent, or Firm—Kevin R. Kepner

[57] **ABSTRACT**

A method and apparatus for measuring colorimetric, gloss and registration data on a substrate exiting a printing machine. A detector using a series of red, green, and blue filters collects image data and maps the collected data to absolute color coordinates. The apparatus is factory calibrated to the specific colorants used in the printing machine. Gloss measurements are made using the same apparatus. Registration data between the various color separations is also obtained and feedback delivered to the various imaging modules. The detector allows on the fly data to be obtained and machine specific corrections to be made.

13 Claims, 5 Drawing Sheets



Attachment F

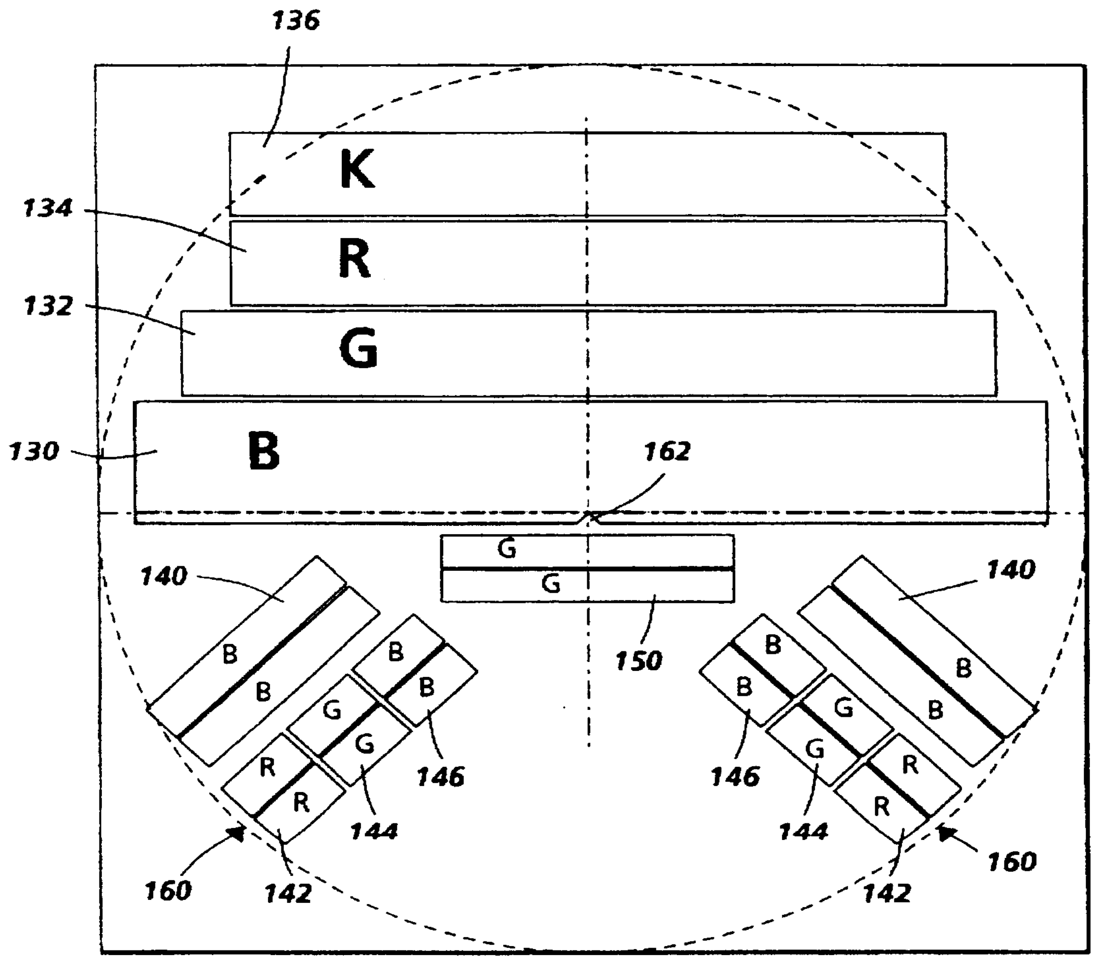

136
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FIG. 1

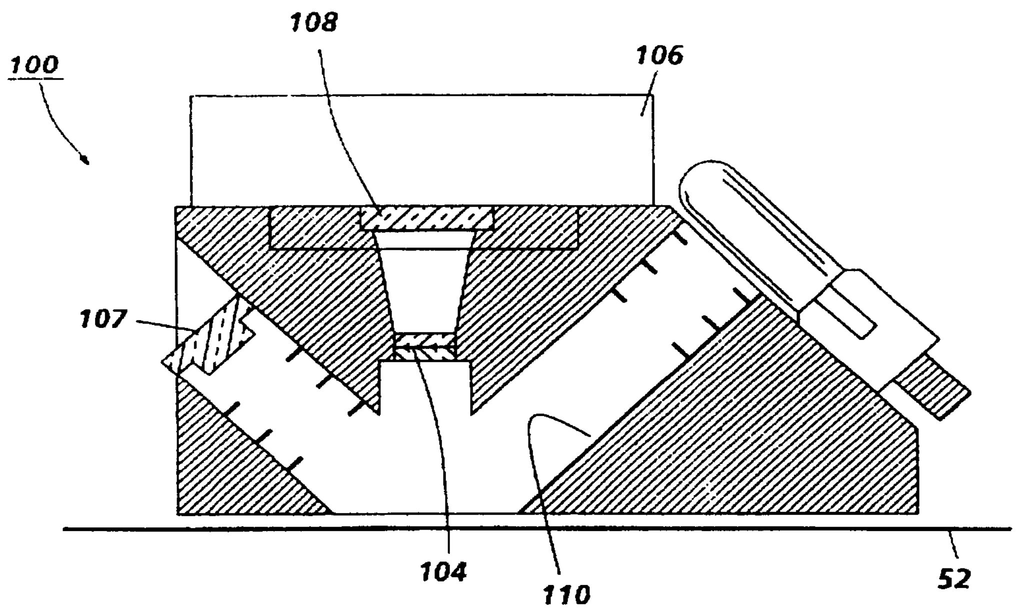

FIG. 2

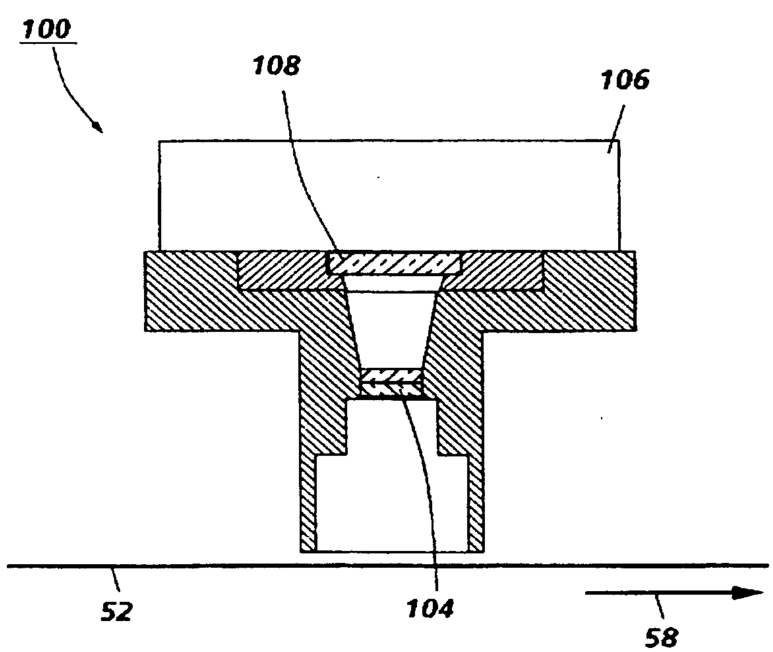

FIG. 3

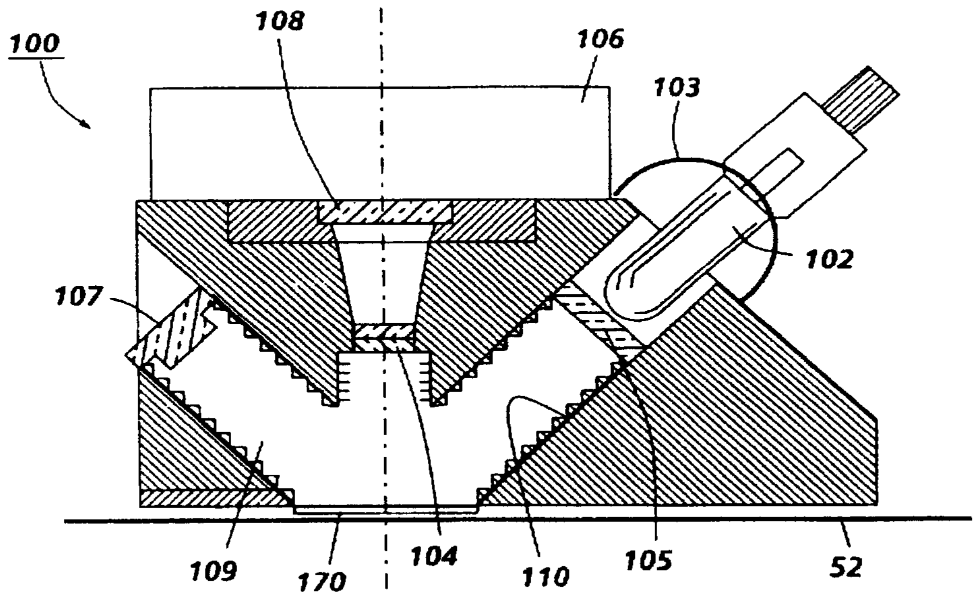

FIG. 4

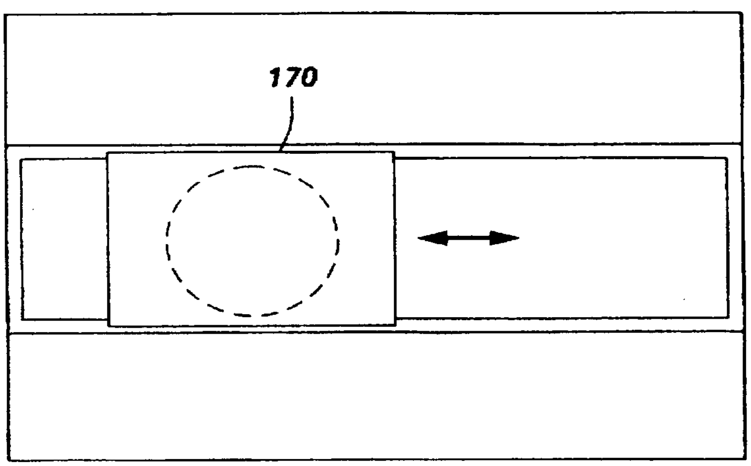

FIG. 5

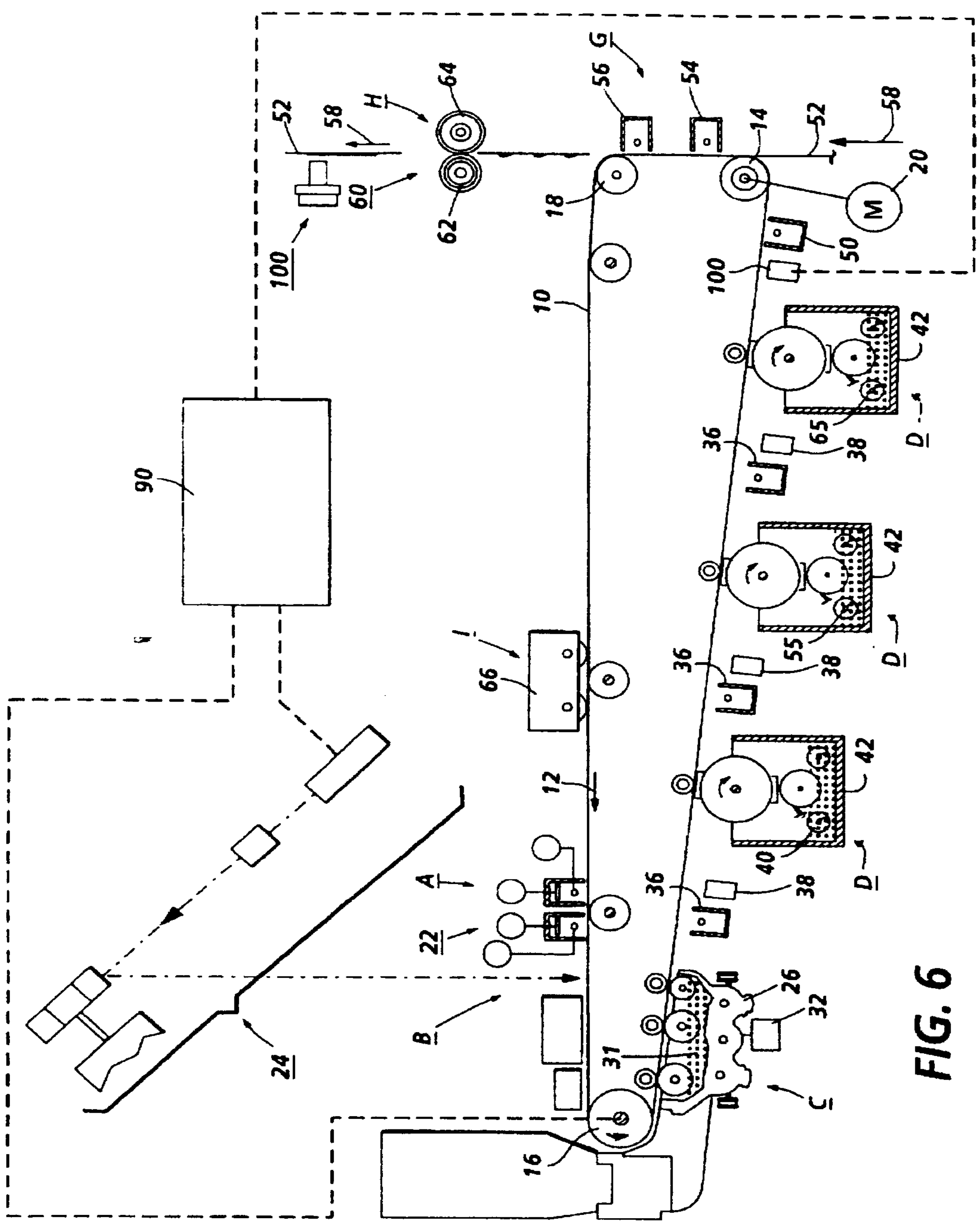

FIG. 6

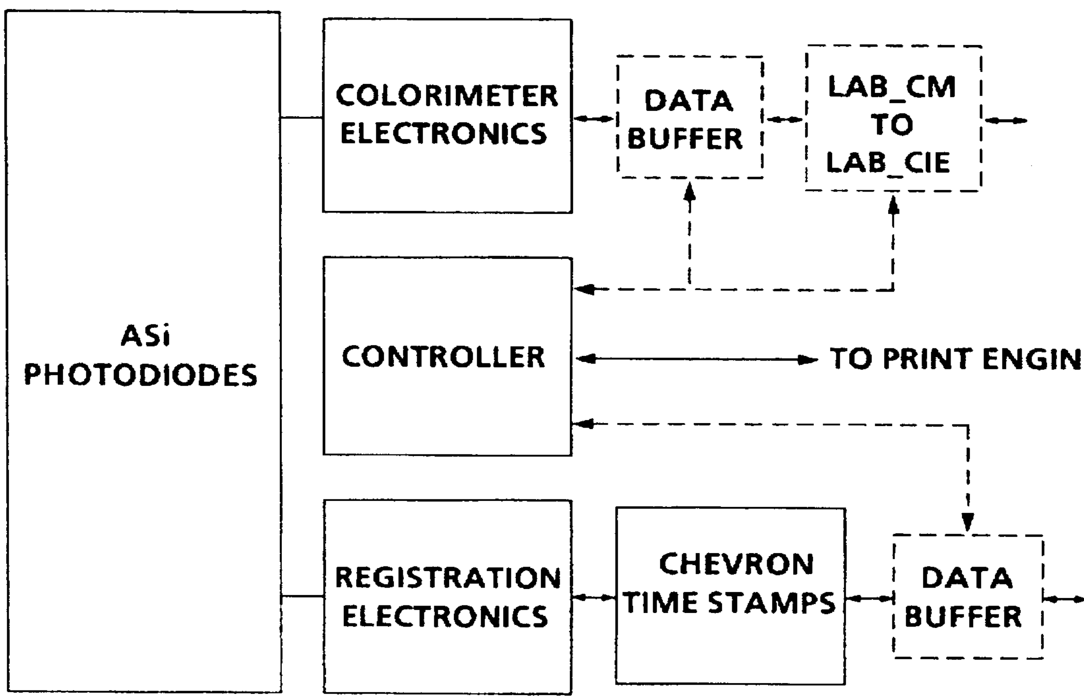
COLORIMETER ELECTRONICS
DATA BUFFER
LAB_CM TO LAB_CIE
ASi PHOTODIODES
CONTROLLER
TO PRINT ENGINE
REGISTRATION ELECTRONICS
CHEVRON TIME STAMPS
DATA BUFFER

FIG. 7

APPARATUS FOR COLORIMETRY GLOSS AND REGISTRATION FEEDBACK IN A COLOR PRINTING MACHINE

This invention relates generally to the calibration, registration and gloss control of color images in a color image output terminal (IOT), and more particularly concerns an improved color image alignment and image quality control system utilizing an improved multifunction sensing and feedback device in full color printing machines including electrophotographic, ink jet, thermal transfer, sublimation and other types. Of these the electrophotographic type will be most used as example in the following diclosure; however, any of the others would have been suitable.

In a typical electrophotographic printing process, a photoconductive member is charged to a substantially uniform potential so as to sensitize the surface thereof. The charged portion of the photoconductive member is exposed to a light image of an original document being reproduced. Exposure of the charged photoconductive member selectively dissipates the charges thereon in the irradiated areas. This records an electrostatic latent image on the photoconductive member corresponding to the informational areas contained within the original document. After the electrostatic latent image is recorded on the photoconductive member, the latent image is developed by bringing a developer material into contact therewith. Generally, the developer material comprises toner particles adhering triboelectrically to carrier granules. The toner particles are attracted from the carrier granules to the latent image forming a toner powder image on the photoconductive member. The toner powder image is then transferred from the photoconductive member to a copy sheet. The toner particles are heated to permanently affix the powder image to the copy sheet.

The foregoing generally describes a typical black and white electrophotographic printing machine. With the advent of multicolor electrophotography, it is desirable to use an architecture which comprises a plurality of image forming stations. One example of the plural image forming station architecture utilizes an image on image system in which the photoreceptive member is recharged, reimaged and developed for each color separation. This charging, imaging, developing and recharging reimaging and developing is done in a single revolution of the photoreceptor in so-called single pass machines, while multipass architectures form each color separation with a single charge, recharge system and imager and multiple developers, one for each color. The single pass architecture offers a potential for high throughput.

In order to deliver good quality images, strict specifications are imposed on the accuracy with which the color image output terminal superimposes the various color separations which compose the individual images. This juxtaposition accuracy is often called registration. In the trade, a limit of 125 micrometers is considered a maximum for acceptable misregistration errors of quality pictorial color images and a 75 micrometer limit is often imposed as a limit by the manufacturers of top quality equipment. Some imaging techniques require registration accuracy of 15 micrometers for pictorial information. An accuracy of 35 micrometers is typically required for the printing of fine colored text. These numbers represent the diameter of a circle which would encompass all supposedly homologous color dots.

Additionally it is important to be able to accurately reproduce colors and print these colors at a desired gloss level. A single device which can determine colorimetric, gloss and registration values from test images is highly desireable in multicolor document output terminals.

One common way of improving registration is described in U.S. Pat. No. 4,903,067 to Murayama et al. Murayama et al. employ a marking system with a detector for measuring alignment errors and mechanically move individual color printers to correct misalignment. Color printers that employ marks produced by each of the constituent colors in juxtaposition with each other enable correction of lateral and longitudinal relative position, skew and magnification.

Measurement of the position of each of the registration marks and the test patches for gloss and colorimetric values may be accomplished by illuminating the marks and employing a lens to collect the diffusely reflected light to image the reflection on photodetectors or photodetector arrays. The illumination is in the visible wavelength. In order to reliably detect the position of the registration mark and the test patches, the diffuse reflection from the marks must be significantly different from its background. It is desirable therefore.

The following disclosures may be relevant to various aspects of the present invention:

U.S. Pat. No. 5,160,946

Inventor: Hwang

Issue Date: Nov. 3, 1992

U.S. Pat. No. 4,965,597

Patentee: Ohigashi et al.

Issued: Oct. 23, 1990

U.S. Pat. No. 4,916,547

Patentee: Katsumata et al.

Issued: Apr. 10, 1990

U.S. Pat. No. 4,804,979

Patentee: Kamas et al.

Issued: Feb. 14, 1989

The relevant portions of the foregoing disclosures may be briefly summarized as follows:

U.S. Pat. No. 5,160,946 to Hwang discloses a registration system for an electrophotographic printing machine which forms registration indicia at a first transfer station and utilizes the formed indicia to register the image at subsequent transfer stations.

U.S. Pat. No. 4,965,597 discloses a color image recording apparatus which superimposes a plurality of different color images on one another to form a composite image. Registration marks are formed on a recording medium and are sensed at each station to assure a clear and accurate superimposed image. A sensor senses one or both edges of a recording medium to note image deviations caused by transport to enable compensation thereof.

U.S. Pat. No. 4,916,547 discloses a color image forming apparatus which produces a single composite color image on a paper. The paper is transported by a belt and the composite color image is formed by transferring image components of different colors to the paper in register with each other. The apparatus reduces positional deviation of a plurality of image components of different colors by sensing signals on a surface of the transfer belt outside a paper region. The

sensor senses arriving pattern images and corrects for unaligned images by calculating a deviation amount and adjusting a timing signal accordingly.

U.S. Pat. No. 4,804,979 discloses a single pass color printer/plotter having four separate microprocessor-based print stations, each for printing a different color image for superimposition with one another to form a full color image. The printer includes a registration system where each print station monitors registration marks to correct for media variations. Each print station includes optical sensors that monitor the marks printed on the media edge to synchronize the printing and align the images properly.

Commercial spectrophotometers and colorimeters such as the Minolta® CM-2002 spectrophotometer and an X-Rite® DTP51 Colorimeter are available to perform various colorimetric and gloss tests, however these devices are slow and require significant set-up time.

In accordance with one aspect of the present invention, there is provided a high speed multi-function sensor for a multi-color printing machine. The apparatus comprises a first detector for determining a colorimetric value of an image and generating a signal indicative thereof, a second detector for determining a gloss value of an image and generating a signal indicative thereof and a third detector for determining a registration value between a plurality of color separations in the image and generating a signal indicative thereof. The fourth detector is a timing (or windowing) mark detector to initiate the above-indicated measurements.

Pursuant to another aspect of the present invention, there is provided a color electrophotographic printing machine. The machine comprises a full color electrophotographic printing machine having an intregral device for determining colorimetric, gloss, and registration values for an image. The device comprises a first detector for determining a colorimetric value of an image and generating a signal indicative thereof, a second detector for determining a gloss value of an image and generating a signal indicative thereof and a third detector for determining a registration value between a plurality of color separations in the image and generating a signal indicative thereof. A fourth detector is a timing (or windowing) mark detector to initiate the above-indicated measurements.

Pursuant to yet another aspect of the present invention, there is provided a method for determining colorimetric, gloss, and registration mark values in a full color electrophotographic printing machine. The method comprises illuminating a test pattern with a light source, detecting the reflected signal from the target pattern, filtering the detected signal with a red, green, and blue filter respectively and converting the filtered signals to a colorimetric ($L^* a^* b^*$) value for the specific colorant in the printing machine. Said conversion depends on dedicated calibration procedures.

Other features of the present invention will become apparent as the following description proceeds and upon reference to the drawings, in which:

FIG. 1 shows the sensor pattern arrangement for using the present invention;

FIG. 2 illustrates a side elevational view of a first embodiment of the combination sensor of the invention herein;

FIG. 3 illustrates an end elevational view of the FIG. 1 sensor;

FIG. 4 illustrates a side elevational view of a second embodiment of the combination sensor of the invention herein;

FIG. 5 illustrates a plan view of the FIG. 4 embodiment illustrating the combination calibration shutter dust cover;

FIG. 6 is a schematic diagram of a four color image output terminal utilizing the device of the present invention; and

FIG. 7 illustates a block diagram of an example of control circuitry for the sensor.

This invention relates to an imaging system which is used to produce color output in a single revolution or pass of a photoreceptor belt. It will be understood, however, that it is not intended to limit the invention to the embodiment disclosed. On the contrary, it is intended to cover all alternatives, modifications and equivalents as may be included within the spirit and scope of the invention as defined by the appended claims, including a multiple pass color process system, and a single or multiple pass highlight color system.

Turning now to FIG. 6, the printing machine of the present invention uses a charge retentive surface in the form of an Active Matrix (AMAT) photoreceptor belt 10 supported for movement in the direction indicated by arrow 12, for advancing sequentially through the various xerographic process stations. The belt is entrained about a drive roller 14, tension rollers 16 and fixed roller 18 and the roller 14 is operatively connected to a drive motor 20 for effecting movement of the belt through the xerographic stations.

With continued reference to FIG. 6, a portion of belt 10 passes through charging station A where a corona generating device, indicated generally by the reference numeral 22, charges the photoconductive surface of belt 10 to a relative high, substantially uniform, preferably negative potential.

Next, the charged portion of photoconductive surface is advanced through an imaging station B. At exposure station B, the uniformly charged belt 10 is exposed to a laser based output scanning device 24 which causes the charge retentive surface to be discharged in accordance with the output from the scanning device. Preferably the scanning device is a laser Raster Output Scanner (ROS). Alternatively, the ROS could be replaced by other xerographic exposure devices such as LED arrays.

The photoreceptor, which is initially charged to a voltage V_0, undergoes dark decay to a level V_{ddp} equal to about −500 volts. When exposed at the exposure station B it is discharged to $V_{background}$ equal to about −50 volts. Thus after exposure, the photoreceptor contains a monopolar voltage profile of high and low voltages, the former corresponding to charged areas and the latter corresponding to discharged or background areas.

At a first development station C, a magnetic brush developer structure, indicated generally by the reference numeral 26 advances insulative magnetic brush (IMB) material 31 into contact with the electrostatic latent image. The development structure 26 comprises a plurality of magnetic brush roller members. These magnetic brush rollers present, for example, charged black toner material to the image areas for development thereof. Appropriate developer biasing is accomplished via power supply 32.

A corona recharge device 36 having a high output current vs. control surface voltage (I/V) characteristic slope is employed for raising the voltage level of both the toned and untoned areas on the photoreceptor to a substantially uniform level. The recharging device 36 serves to recharge the photoreceptor to a predetermined level.

A second exposure or imaging device 38 which may comprise a laser based input and/or output structure is utilized for selectively discharging the photoreceptor on toned areas and/or bare areas, pursuant to the image to be developed with the second color developer. At this point, the photoreceptor contains toned and untoned areas at relatively

high voltage levels and toned and untoned areas at relatively low voltage, levels. These low voltage areas represent image areas which are developed using discharged area development (DAD). To this end, a negatively charged, developer material 40 comprising color toner is employed. The toner, which by way of example may be yellow, is contained in a developer housing structure 42 disposed at a second developer station D and is presented to the latent images on the photoreceptor by a of a magnetic brush developer roller. A power supply (not shown) serves to electrically bias the developer structure to a level effective to develop the DAD image areas with negatively charged yellow toner particles 40.

The above procedure is repeated for a third imager for a third suitable color toner such as magenta and for a fourth imager and suitable color toner such as cyan. In this manner a full color composite toner image is developed on the photoreceptor belt.

To the extent to which some toner charge is totally neutralized, or the polarity reversed, thereby causing the composite image developed on the photoreceptor to consist of both positive and negative toner, a negative pre-transfer dicorotron member 50 is provided to condition the toner for effective transfer to a substrate using positive corona discharge.

Subsequent to image development a sheet of support material 52 is moved into contact with the toner images at transfer station G. The sheet of support material is advanced to transfer station G by conventional sheet feeding apparatus, not shown. Preferably, the sheet feeding apparatus includes a feed roll contacting the uppermost sheet of a stack copy sheets. The feed rolls rotate so as to advance the uppermost sheet from stack into a chute which directs the advancing sheet of support material into contact with photoconductive surface of belt 10 in a timed sequence so that the toner powder image developed thereon contacts the advancing sheet of support material at transfer station G.

Transfer station G includes a transfer dicorotron 54 which sprays positive ions onto the backside of sheet 52. This attracts the negatively charged toner powder images from the belt 10 to sheet 52. A detack dicorotron 56 is provided for facilitating stripping of the sheets from the belt 10.

After transfer, the sheet continues to move, in the direction of arrow 58, onto a conveyor (not shown) which advances the sheet to fusing station H. Fusing station H includes a fuser assembly, indicated generally by the reference numeral 60, which permanently affixes the transferred powder image to sheet 52. Preferably, fuser assembly 60 comprises a heated fuser roller 62 and a backup or pressure roller 64. Sheet 52 passes between fuser roller 62 and backup roller 64 with the toner powder image contacting fuser roller 62. In this manner, the toner powder images are permanently affixed to sheet 52 after it is allowed to cool. After fusing, a chute, not shown, guides the advancing sheets 52 to a catch tray, not shown, for subsequent removal from the printing machine by the operator. The sensor device 100 of the present invention is located in the paper path between the fuser assembly 60 and the catch tray. The fused target substrate 52 is passed by the sensor and a sample image is scanned for calibration purposes as described below.

After the sheet of support material is separated from photoconductive surface of belt 10, the residual toner particles carried by the non-image areas on the photoconductive surface are removed therefrom. These particles are removed at cleaning station H using a cleaning brush structure contained in a housing 66.

It is believed that the foregoing description is sufficient for the purposes of the present application to illustrate the general operation of a color printing machine.

Turning now to FIGS. 1–5 inclusive, for clarity and convenience, the schemes will be described in terms of chevron marks and bicell detectors such as those described in U.S. Pat. No. 5,287,162, the pertinent portions of which are herein incorporated by reference.

The main feature of the sensor device is the color measurement. The color-to-color registration enables the sensor to be used either in place of a MOB (Mark-on-Belt) sensor, or whenever the toners are indistinguishable from each other in infrared lighting (the MOB illumination source). The gloss measurement is an additional feature which helps control another important quality characteristic of the printer output.

The conceptual basis of the design is to measure color by imaging a part of an illuminated color patch on three amorphous silicon detector elements after filtering with red, green, and blue materials. The technology is akin to that of color input scanners. The detector outputs can be used as densitometric values to assure color constancy. Calibration of the resulting instrument outputs against measurement by laboratory colorimeters taken over a large sample of patches made by the toners of the printer of interest allows mapping to absolute color coordinates (such as L*a*b*). A mobile dust cover 170 (FIG. 5) is used to prevent excessive contamination and doubles in its function in presenting a white sample to the device for drift correction purposes.

Color-to-color registration errors are measured by the same chevron mark technology successfully employed in MOB sensors. The only difference is that the operation is performed in the visible range and the same illumination, optics and detector chip as in the color measurement are used. Bi-cell detectors 140,142, 144, 146 (FIG. 1) on the chip perform this function. To improve measurement contrast red, green and blue filters are also used on these bi-cells. The red-filtered photodiodes are used to measure the relative positions of the cyan and black registration marks; while the green-filtered photodiodes are used to measure the relative positions of the magenta and black registration marks; and the blue-filtered photodiodes are used to measure the relative positions of the yellow and black registration marks. The rows of bicell photodiodes, groups 160, are arranged to align with the optical center in order to eliminate any deleterious effects of barreling or pin-cushioning. The auxiliary blue-filtered bicell photodiodes, group 140, are not so aligned, and as a result, the image of straight registration marks may be subject to curvature. So long as this effect is understood, the auxiliary blue-filtered bicells 140 can be advantageously used for extending the lateral capture range in coarse registration procedures and for obtaining larger signals from yellow marks.

Gloss is measured at a 45 degree specular angle by means of a green-filtered amorphous silicon detector 107. In the present configuration no optical elements are included so that some diffuse reflection may add to the signal. However, this error should be tolerable.

The reflectance values measured by the sensor elements are mapped to corresponding laboratory spectrophotometer CIELAB values (e.g., for D50/2 deg) by use of neural networks. Specifically, the factory calibration proceeds as follows. A number of color patches are printed using the toners from the target printer family using a printer representative of that family. The color of the patches are selected

so as to adequately represent the volume and surface of the printer's color gamut. The CIELAB coordinates of the patches need to be measured once using the spectrophotometer and the data stored. These same patches are then measured by means of the sensor of this invention. The data set from the sensor, together with the corresponding spectrophotometer results, is then used to create a mapping between the sensor's rgb space to the CIELAB color space. The fidelity of the mapping on several test patches is verified and evaluated for the specific toners used in the printer. Once a valid network is built for a specific set of toners, it can be exercised with any test patch printed using those toners to produce absolute measurements (L*a*b*). The parameters representing the mapping are then stored in permanent memory onboard the sensor for field use. Depending upon manufacturing tolerances and desired color accuracies, this factory calibration procedure can be followed for each sensor. Alternatively, this procedure can be followed using data from sensors selected according to quality control audits of a batch build. The parameters obtained from factory calibration of the selected sensors could then be stored permanently onboard the remaining sensors in the batch (as well as those that were tested). The neural network is the most general and can be implemented with data which are not organized in a rectangular grid. On the other hand, these networks are computationally intensive not only during their learning phase but also in their application phase. Therefore, a possible course of action is to use the learned neural network to generate data with inputs on a rectangular mesh so that mapping in real use can be performed by straight forward linear interpolation. Under these conditions, the rectangular mesh would also be created once during factory calibration.

Amorphous silicon was chosen because of its low cost for the rather large detector area (9×9 mm), because of its low dark reverse current and because of its insensitivity to infrared radiation. Crystalline silicon could also be used with the appropriate filtering. (Note that amorphous silicon also needs a detector trimming filter to eliminate unwanted effects of infrared sensitivity). The sensor **100** location is downstream of the fuser as shown in FIG. **6**.

The subject invention can be produced at a very low cost and it can compete with much more expensive instruments because it is calibrated against the specific toners with which it is going to be used in a printer and can be mass produced.

One of the major contributing factors in the low cost implementation of this sensor in a DOT is the utilization of mixed-signal LSI technology. This allows the conversion of the aSi photodiode outputs into a usable signal level to enable high speed measurements in DOT's with high process speeds. Included on the chip is a precision integration capacitor. This allows conversion of currents of less than 500 femtoamps to be repeatably measured with a signal to noise ratio greater than 80 dB. This excellent performance gives the sensor the capability of measuring color patches with integration times on the order of 1 millisecond or less. FIG. 7 illustates a block diagram of an example of control circuitry for the sensor.

The operation of the detector **100** for colorimetry and registration measurement is based on imaging the diffuse reflection of the illuminated target **52** onto a detector at 1:1 magnification to take advantage of symmetry in minimizing image defects. The essential geometry of the colorimetry and registration detector chip is shown in the drawing of FIG. 1. It occupies an 8 mm×8 mm area. A description of the functions are as follows:

Colorimetry is performed by the four large rectangular areas near the top of the figure. The pattern lies within the 4 mm radius field of view with the increasing area dedicated to weaker signals (i.e., the blue pattern **130** is the largest at 7.4 mm×1.1 mm, the green pattern **132** is 6.6 mm×0.75 mm, and the red signal **134** is expected to be the strongest and therefore allocated the smallest area of 5.8 mm×0.75 mm).

Even in the absence of light, depending upon the electrical bias, there may be a signal out of the photodiode, which is significantly temperature dependent. This signal is due to the so-called dark reverse current. If this current is measured before each reading is taken, and then subtracted from the total reading, there is no loss of accuracy. However, this repetitive procedure imposes measurement delay and induces life limiting stress on the sensor components by the cycling it implies. The black-filtered photodiode **136** has an output which continuously measures dark reverse current irrespective of whether the lamp is ON or OFF. It must be assumed, of course that the dark reverse current density is the same in the four elements **130**, **132**, **134** and **136**. This allows keeping the lamp ON for color measurements only. The output of the black pattern **136** can be used to compensate for drift of temperature dependent parameters through feedback control. Filters such as Brewer Science polyimides are suitable for use such as: Red 101, Green 103, Blue EXP93006 (aka, ExpBlue#4).

Registration detection is performed using segmented bi-cells **140**, **142**, **144**, **146** arranged in a chevron pattern. The blue channel, being the weakest expected signal, has additional surface dedicated to it. Each of the smaller bi-cell halves **142**, **144**, **146** are 0.7 mm×0.4 mm. The larger blue bi-cell halves **140** are 1.9 mm×0.4 mm.

The timing mark and image artifact detector is the horizontal green bicell pattern **150** in the middle of the sensor and measures 2.4 mm×0.29 mm. It is used to facilitate the windowing problem by detecting separation marks placed between the color patches. This approach makes it possible to accurately locate the target patch with reduced resource requirements. Specifically, the colorimetric measurements would be triggered a specific time delay after a timing mark, such as a line across the process direction approximately 0.29 mm thick and more than 2.4 mm wide, is detected. The motivation for following this procedure is that the noise within a half-tone color sample patch places a restriction on its minimal size even if the measurement system does not. In the interest of measurement efficiency, provision is made to provide sufficient sample sizes in a layout of test samples which does not waste space. When a filtered photodiode is known to be within the moving image of a color sample, the signal from the photodiode is continuously integrated. Accurate starting and stopping of this integration affords maximum signal efficiency and is enabled by accurate "windowing". In practice, a timing mark would be placed between every "N" color samples.

There are two triangular alignment marks **160** at the perimeter of the sensor near the red bi-cells **142**. A third mark **162** is a triangular relief in the blue colorimetry pattern **130**. This mark also indicates the sensor's optical center. The marks are used during assembly of the chip on the electronics board. The chips will use either standard 24 pin DIPs or chip-on-board technology. With this later technology, the amorphous silicon die is directly mounted and electrically connected to a printed circuit substrate.

Gloss detection is performed by a separate chip. A green filter coating (such as Brewer 103) can be applied to limit the signal to the wavelength distribution characterizing the human eye. The detector has an active rectangular area of 6.4 mm×3.2 mm and is shown in FIGS. **2** and **4** as **107**.

FIG. 2 illustrates a general arrangement of the sensor with the illumination source 102, the optics 104, the detectors 106 and the trimming filter 108. The illumination is provided by a tungsten-halogen lamp (ie. Sylvania 1990). In one configuration the lamp filament was located two inches from the target and without intervening optics. This resulted in good performance but insufficient light to take a reading in 0.25 inches of travel in a 1000 mm/sec printer of a target patch with an optical density greater than 2.

In order to increase the lighting, a second embodiment as illustrated in FIG. 4 was developed. The lamp 102 was placed at 1.5 inches from the target, a curved reflector 103 was placed behind it, and a light diffuser 105 was added in the light path 109. With this configuration, the 0.25 inch square measurement patch can be achieved at 1000 mm/sec. This measurement area was selected as a minimum in order to avoid noise due the halftone pattern. However, longer patches are undesirable due to the waste of space.

The lenses used are 6 mm in diameter which can be adjusted in size depending on the application. Two configurations of lenses are suggested: a) two plano-convex lenses assembled belly-to-belly; b) two doublet achromat lenses assembled belly-to-belly. An aperture washer is located between the lenses. The apertures are holes 3 or 4.5 mm in diameter in a 0.5 mm thick black washer. Lenses can be a molded plastic material. All internal light passages are round and have sharp tooth threads 110 to minimize stray light paths. After the lenses the light crosses an infrared filter 108 which acts as a detector trimmer. Its task is to eliminate the narrow region of sensitivity of the amorphous silicon in the infrared region of the spectrum. An example of a suitable filter is an ORIEL 51980 (a BG38 style) filter.

The sensor may also be used for optical density grayscale detection and gloss detection in black and white printers. The optical density can be determined by utilizing the green channel of the sensor to measure the density of the black toner or ink.

In recapitulation, there is provided a method and apparatus for measuring colorimetric, gloss and registration data on a substrate exiting a printing machine. A detector using a series of red, green, and blue filters collects image data and maps the collected data to absolute color coordinates specific to the colorants used in the printing machine. Gloss measurements are made using the same instrument. Registration data between the various color separations is also obtained and feedback delivered to the various imaging modules. The detector allows on the fly data to be obtained and machine specific corrections to be made.

It is, therefore, apparent that there has been provided in accordance with the present invention, a colorimetry, gloss and registration detection device that fully satisfies the aims and advantages hereinbefore set forth. While this invention has been described in conjunction with a specific embodiment thereof, it is evident that many alternatives, modifications, and variations will be apparent to those skilled in the art. Accordingly, it is intended to embrace all such alternatives, modifications and variations that fall within the spirit and broad scope of the appended claims.

We claim:

1. A multi-function sensor for measuring registration, gloss and colorimetric values of a test patch image printed on a substrate in a multi-color printing machine, comprising:

a first detector for determining a colorimetric value of the image and generating a signal indicative thereof;

a second detector for determining a gloss value of the image and generating a signal indicative thereof; and

a third detector for determining a registration value between a plurality of color separations in the image and generating a signal indicative thereof;

a fourth detector for internal sensor parameter compensation.

2. An apparatus according to claim 1, wherein said first detector comprises:

a red filter;

a blue filter;

a green filter; and

a converter to convert a red, green, and blue signal to an absolute colorimetric value.

3. An apparatus according to claim 2, wherein said converter is specifically mapped to the colorants utilized in the printing machine.

4. A method for determining colorimetric, gloss, and registration mark values in a full color electrophotographic printing machine, comprising:

illuminating a test pattern with a light source;

detecting the reflected signal from the test pattern;

filtering the detected signal with a red, green, and blue filter respectively; and

converting the filtered signals to colorimetric (L* a* b*) values and gloss values for the specific colorant in the printing machine while measuring the position of the relative color separations and generating signals indicative thereof.

5. A full color electrophotographic printing machine having an integral device for determining colorimetric, gloss, and registration values for a test patch image, comprising:

a first detector for determining a colorimetric value of the image and generating a signal indicative thereof;

a second detector for determining a gloss value of the image and generating a signal indicative thereof; and

a third detector for determining a registration value between a plurality of color separations in the image and generating a signal indicative thereof.

6. A printing machine according to claim 5, wherein said first detector comprises:

a red filter;

a blue filter;

a green filter; and

a converter to convert a red, green, and blue signal to a colorimetric value.

7. A printing machine according to claim 6, wherein a converter is specifically created for the colorants utilized in the printing machine.

8. A multi-function sensor for measuring registration, gloss and colorimetric values of a test patch image printed on a substrate in a multi-color electrophotographic printing machine, comprising:

a first detector for determining a colorimetric value of the image and generating a signal indicative thereof;

a second detector for determining a gloss value of the image and generating a signal indicative thereof; and

a third detector for determining a registration value between a plurality of color separations in the image and generating a signal indicative thereof;

a fourth detector for internal sensor parameter compensation.

9. A sensor according to claim 8, wherein said first detector comprises:

a red filter;

a blue filter;

a green filter; and

a converter to convert a red, green, and blue signal to an absolute colorimetric value.

10. A sensor according to claim 9, wherein said converter is specifically mapped to the colorants utilized in the printing machine.

11. A multi-function sensor for measuring gloss and optical density values of a test image printed on a substrate in a black and white printing machine, comprising:

a first detector for determining a density value of the image and generating a signal indicative thereof; and

a second detector for determining a gloss value of the image and generating a signal indicative thereof.

12. A sensor according to claim 11, wherein said first detector comprises:

a green filter; and

a converter to convert a green signal to an absolute density value.

13. An integral apparatus for measuring registration, gloss and colorimetric values of a test patch image printed on a substrate, comprising:

a first detector for determining a colorimetric value of the image and generating a signal indicative thereof;

a second detector for determining a gloss value of the image and generating a signal indicative thereof; and

a third detector for determining a registration value between a plurality of color separations in the image and generating a signal indicative thereof.

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